THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
Fredericton, New Brunswick

1987 SAINT JOHN RIVER FLOODING

January 1988

Acres International Limited
Niagara Falls, Ontario

SUMMARY

The ice regime of the Saint John River exhibits a typical pattern of ice breakup and ice jam flooding in late March and early April. A series of locations along the river are recognized as common lodgement points for ice jams. The specific jamming situations and the severity of flooding vary from year to year.

Ice jam flooding was extensive in the period April 1 to 5, 1987. The circumstances of this flooding are documented herein. Measurements, observations and inferences from various sources are assembled into a single overall record of the events. The resulting chronology is illustrated by plots of observations and by selected photographs.

Rapid snowmelt in the period between March 20 and 31, 1987, coupled with a moderate amount of rainfall, produced the highest ice breakup flows on record. Ice from the upper reaches of the Saint John River, as far away as St. Francis, was carried downstream in a series of ice runs and jamming events over the next five days, eventually lodging at Sullivan Creek approximately 33 miles upstream from the Mactaquac dam. There was extensive damage at a number of locations as a result of the large quantities of ice combined with the high river flows.

Some consequences of the 1987 ice jam flooding were more severe than have been experienced before. From a detailed examination of ice, meteorologic and river flow conditions it is concluded that ice conditions were typical, meteorologic conditions leading to snowmelt were unusually severe, and that the river flows at the time of breakup were exceptionally severe.

The unusually severe 1987 floods extended through the north-eastern United States and parts of Quebec. Eight rivers in neighboring basins experienced flooding in the first few days of April. In six of these cases the flooding resulted from ice jamming.

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1 - INTRODUCTION

1 - INTRODUCTION

The breakup of ice in the Saint John River caused extensive flooding in the period April 1 to 5, 1987.

Flooding has frequently occurred along the river in the past. Some features of the 1987 events were more severe than have been experienced before.

This report has two principal objectives:

(a) to document the 1987 events by assembling measurements, observations and inferences from various sources into a single comprehensive chronology. Sections 2 and 3 address this objective.

(b) to put the Saint John River flooding of 1987 in context, both in terms of what happened in neighboring basins this year and in terms of events in the Saint John River valley in past years. Section 4 addresses this objective.

2 - THE ICE REGIME OF THE SAINT JOHN RIVER

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The development and depletion of the ice cover on the Saint John River follows a typical cycle each year. In December, water temperatures reach the freezing point and ice in various forms begins to appear in the river. A stable ice cover forms quite quickly and continues to grow at a declining rate until that growth is interrupted by warm weather and the increasing river flows which accompany it. The following sections describe typical circumstances during the freeze-up period, the winter thaw and the breakup period.

2.1 - The Freeze-Up Period

During the period September to December the flow in the river gradually increases in response to fall storms. The monthly fall flows typically peak in November at about 20 000 ft^3/s (at East Florenceville) and then begin to drop to winter values which are normally less than the summer flows. As a consequence of cold weather, runoff declines and any precipitation is stored on the ground as snow. Low flows prevail in January and February and vary from year to year in the range of about 7000 to 15 000 ft^3/s.

In tranquil reaches of the river, and in reservoirs, ice crystals forming on the water surface are readily able to link together to form an ice sheet. This orderly development of ice sheets, without any significant mechanical disturbance, is referred to as 'thermal growth' of the ice cover. The term 'thermal ice' is used throughout this report to refer to ice formed by this process. As soon as ice covers the surface, the rate at which the water cools is markedly reduced and consequently the rate of freezing diminishes. Experience and theory both show that the ice thickness reached in quiescent areas is approximately proportional to the square root of the number of

degree-days[1] of freezing. In practical terms this means that after one quarter of the cooling effect of the winter the ice thickness has reached half of the ultimate thickness; after half of the cooling, 70% of the thickness is reached, and so on. The influence of snow cover is to act as insulation and thereby reduce the rate of ice growth.

In central New Brunswick, ice thicknesses on ponds and on deep water parts of rivers typically reach 24 inches. The variation from year to year is not great. The ice thickness ranges from approximately 16 to 34 inches.

Where there is some disturbance of orderly freezing by wind waves and turbulence or by the velocity of the flow, ice crystals may be swept away as they form, or the thin ice cover broken and moved before it is strong enough to withstand the imposed forces. (A traditional rule of thumb states that an ice sheet will form only where the water velocity is less than 1.25 ft/s, and once formed, will only stay in place if the velocity remains less than 2.5 ft/s.) The result of the water surface remaining exposed to the atmosphere is that cooling continues at the initial rapid rate and a very great quantity of ice can form in a short period of time. This mechanism can result in ice accumulations that are much thicker than for thermal ice growth.

Most of the river eventually becomes ice covered through mechanical aggregation of the accumulating mass of ice until finally the process of freezing is almost totally inhibited as open water areas become closed off. In some rivers, the freeze-up process takes many weeks and results in massive ice jams and staging of 30 feet or more during formation of the ice cover. By comparison, freeze-up staging on the Saint John River is small. However, the same basic processes can be observed. At some locations the remnants of ice jams that formed during freeze up can persist throughout the winter and contribute to

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[1]A degree-day is defined as a deviation of 1 degree from the freezing temperature for a 1-day period. A freezing degree-day is a deviation of 1 degree below the freezing temperature for a 1-day period.

the lodgement of spring ice jams. The following sections describe the various kinds of mechanical aggregation that occur.

2.1.1 - Border Ice Growth

In reaches of the river where the velocity is too high to permit sheets of ice to stay in place, ice crystals and small pans are swept downstream as they grow. The ice crystals form a moving slushy mass and are very adhesive. In shallow water the velocity at the edge of the river is less and the ice is able to form a bond with the shoreline. The result is a widening zone of border ice along the riverbanks and around islands as slush ice becomes 'buttered' onto the edge of the border ice. At some river sections this process may narrow the open water surface to the extent that arching can occur, permitting a stationary ice cover to begin to form across the entire river width.

2.1.2 - Advance of the Ice Cover Upstream

Slush ice which is conveyed downstream in the rapidly flowing reaches of the river eventually comes to rest against an ice cover in a low velocity reach or in a reach where a closure has already occurred. If the velocity is low enough the ice simply accumulates upstream in front of the cover. A hydrodynamic equilibrium condition determines the thickness of the advancing cover in relation to the velocity and stage at that location. The equilibrium condition is determined by the Froude number[1] of the flow in front of the ice cover.

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[1]The effect of gravity upon the state of flow is represented by a ratio of inertial forces to gravity forces. The ratio is given by the Froude number defined as $F_r = V/\sqrt{gD}$ where V is the mean velocity of flow, g is the acceleration of gravity, and D is the hydraulic depth.

If the Froude number is too high (i.e. large velocity and shallow depth), the ice front may not be able to progress upstream at all. In that case the flowing slush ice will be swept under the ice cover and transported in the flow to a downstream location of low velocity where it is able to come to rest. Eventually these underwater accumulations of ice will impose restrictions on the conveyance of the river at the downstream locations, leading to an increase in water levels at upstream locations. After a time, the water level will be backed up enough for the Froude number requirements to be satisfied and the ice front will continue its upstream development.

2.1.3 - Thickening of the Ice Cover

The upstream progression of the ice front leads to the compression of the unconsolidated mass of slush ice and small ice pieces. At any location the ice cover must support the weight and drag forces imposed on the ice which are not transferred to the banks of the river. Early in the freeze-up period, when the strength of the ice cover is not great, it is common for the ice cover to collapse under the compression forces in a series of 'shoves' which thicken it and enable it to develop greater mechanical resistance. This process generally governs the thickness of the ice cover which forms on the upper Saint John River in those reaches outside the reservoirs.

Once the ice cover is formed, progressive freezing will solidify and strengthen it throughout the remainder of the winter.

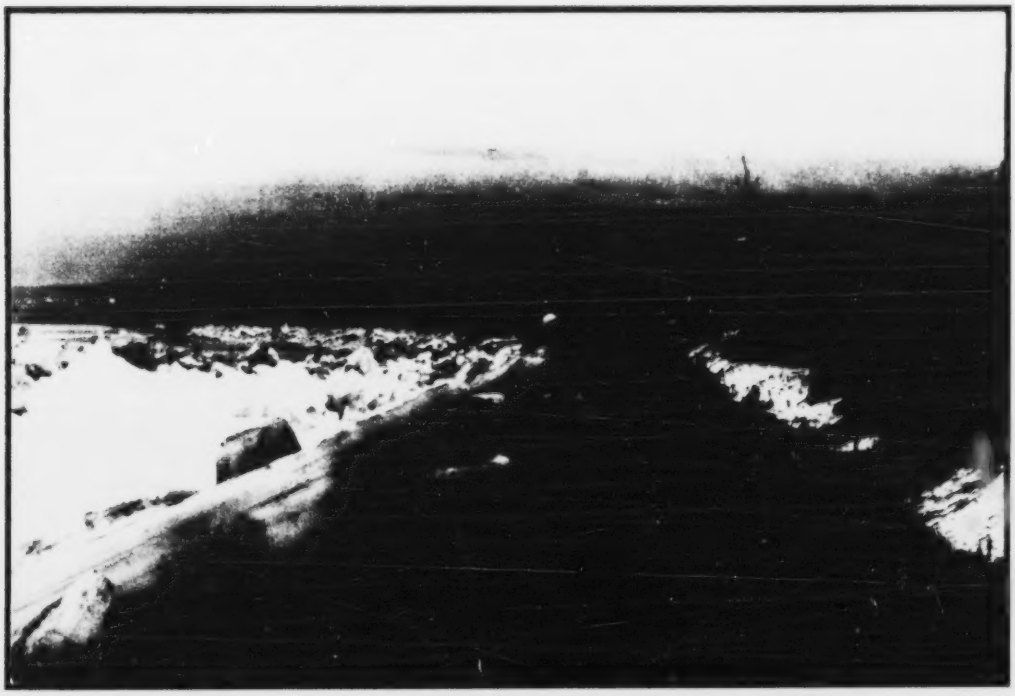
The ice cover can be further thickened through the effects of snowfall, rain and water level changes. Precipitation on the cover generally becomes incorporated as part of the surface ice sheet. Snow compacts over time, hardens and becomes bonded to the ice sheet, sometimes with rain absorbed and incorporated. Very heavy falls of wet snow can cause the ice sheet to be

submerged and the resulting flooding can be a very important factor in the formation of exceptionally thick and strong ice. Observers can easily distinguish the part of the ice sheet which was formed by simple freezing of the surface of the water and they commonly refer to it as 'blue ice'. Photograph 2.1 illustrates part of the thickened ice cover which was shoved up on the shoreline during the 1987 flooding. The stratification caused by snow compaction, wetting and refreezing can be clearly seen in this photograph. Photograph 2.2 shows the typical appearance of the ice cover at the end of the winter.

2.1.4 - Influences of Reservoirs

Immediately downstream from any reservoir the cooling of the water is delayed by the influence of heat from the deeper reservoir water. Throughout the winter the water released from a reservoir is a fraction of a degree warmer than the freezing point and this leads to a short 'standoff' distance of open water immediately downstream. In midwinter the rate of cooling at the open water surface is very rapid. The standoff distance varies with the weather and the rate of outflow. The length of the open water reach therefore varies, and the thin ice cover downstream is alternately thickening by freezing or eroding through melting all winter long. This balance is referred to as a thermal equilibrium.

This same thermal equilibrium prevails under the ice cover throughout the length of the river. The water temperature remains just marginally above the freezing point but, in spite of the vigorous mixing imposed by the water flow, it is not perfectly uniform. There are several sources of heat--for example, the heat equivalent of hydraulic energy dissipated in flowing water, heat conducted from the underlying earth and heat from water above the freezing point entering the river from springs and tributaries. The effects of this heat result in



PHOTOGRAPH 2.1 **THICKENED ICE COVER SHOVED ON SHORE**
LOCATION: UPSTREAM FROM NEWBURG
TIME/DATE: 15:47 - APRIL1, 1987

PHOTOGRAPH 2.2 **TYPICAL END OF WINTER ICE COVER**
LOCATION: MEDUCTIC LOOKING DOWNSTREAM
TIME/DATE: 18:06 - APRIL 1, 1987

the gradual smoothing and, in some locations, thinning of the ice cover and the establishment of a thermal equilibrium ice thickness. Rather than the ice cover gradually thickening by freezing at ever-decreasing rates as the thermal insulation value of the ice increases through the winter, a point is reached where the rate of heat supply just balances the rate of cooling. Due to the complex geometry of the river and the uneven distribution of the supply of heat, the equilibrium thickness varies widely, and in some locations, where warm water is directed to the surface by prevailing currents, open water appears in the ice cover even in midwinter.

There can be some mechanical breakup of the ice cover downstream from a reservoir due to variations in winter outflows. This process can lead to an ongoing buildup of ice in the downstream reach. However, these same reaches are affected by melting due to the heat from the reservoir, and so the total effect on the amount of ice present can only be learned by observation. In order to minimize the mechanical breakup of the downstream ice cover during freeze-up and breakup periods, attempts are made to maintain a constant Beechwood plant outflow.

2.2 - Winter Thaw

In some years, a period of unseasonable warm weather during the winter results in a period of increasing river flows followed by local ice breakup, ice jamming and sometimes flooding. The resulting ice jams may undergo further consolidation and freezing when normal winter temperatures return. Ice jamming during late March and early April has sometimes been traced to the presence of residual ice jams formed during midwinter thaw events.

2.3 - The Breakup Period

At the beginning of the normal breakup period there is a general warming of the weather resulting in some daytime softening of the ice surface. The equilibrium ice thickness is reduced by melting of the ice cover. Areas where there was a thin ice cover or open water during the winter become enlarged areas of open water. Photograph 2.2 shows the typical appearance of the ice cover just prior to breakup.

The same warm weather conditions cause snowmelt throughout the watershed which in turn causes progressively higher river flows. The resulting rise in the water level causes dislocation of the ice cover along the shoreline as well as an increase in the forces acting on the ice cover.

The ice cover begins to break up at locations where the increasing forces exceed the declining strength, setting in motion a sequence of breakup events. For example, in 1987 breakup was initiated in the vicinity of Fort Kent at a river flow of 30 000 to 40 000 ft^3/s on March 30. The next morning, ice runs were observed above the Beechwood headpond at about the same flow, and in the reach downstream from Beechwood at about 50 000 ft^3/s.

2.3.1 - The Progression of Breakup

The breakup of the ice cover leads to ice processes similar to those which influenced the initial formation of the ice cover. As breakup is initiated, a large portion of the broken ice is dislodged and swept downstream. This broken ice then reaches a location where lodgement occurs. Lodgement can occur against a stationary ice cover and/or at a channel constriction. The channel constriction could consist of a natural channel narrowing or reduction in depth, and/or a manmade constriction such as a bridge. At this lodgement location, stability, thickening and instability processes occur. These processes are similar to

those described for cover formation in Sections 2.1.2 and 2.1.3. Some ice is left behind in shallow areas and attached to the banks and progressively the total volume of ice is diminished through melting.

From each separate open area, breakup proceeds from upstream to downstream. The mass of broken ice is pushed downstream against and under the remaining solid ice cover. Thrust and lifting forces are imposed against the stationary winter cover which undergoes progressive breaking with the broken pieces adding to the volume of the ice run. The broken ice pieces form a temporary unconsolidated ice cover which shoves and flows downstream (an ice run) or lodges and thickens as needed to achieve equilibrium (an ice jam). Photograph 2.3 shows the progressive breaking that occurs at the 'head'[1] of a jam. The progress of the ice run at this stage of development of ice jams has been described as a 'melee' of broken, upturned and stranded ice pieces which frequently scour the shoreline as they crowd their way downstream.

Due to the restriction imposed on the river flow by the accumulating ice mass, water levels rise upstream.

The ice jams remain quite stable if the river flow and the quantity of ice upstream do not increase. Changes in river flow will always influence jam stability, whereas the effect of ice volume on jam stability diminshes as the volume in the jam increases. During the breakup period, however, the flow and ice quantity are generally changing hour by hour and the unconsolidated ice jam changes accordingly.

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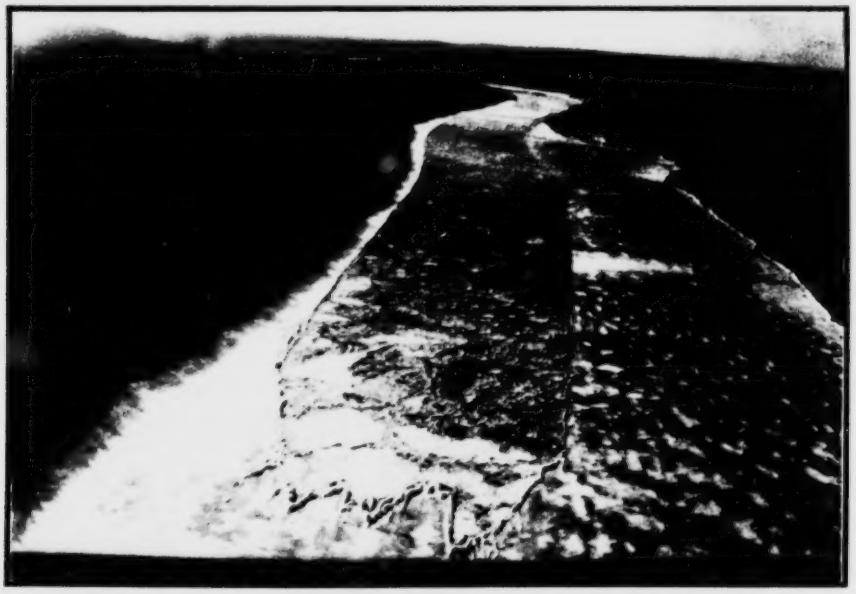
[1]In this report the downstream extremity of the ice jam is designated the 'head' of the jam and the upstream end is called the 'tail'. (These designations are sometimes reversed by other investigators.)

PHOTOGRAPH 2.3 **PROGRESSIVE BREAKING THAT OCCURS AT THE HEAD OF A JAM**
LOCATION: UPPER KENT AIRSTRIP
TIME/DATE: 11:36 - APRIL 1, 1987



PHOTOGRAPH 2.4 **SULLIVAN CREEK ICE JAM JUST BEFORE FINAL LODGEMENT**
LOCATION: TEMPLE
TIME/DATE: 16:30 - APRIL 2, 1987

2.3.2 - Lodgement and Dislodgement

The locations at which moving ice can find support and remain stationary for a time are dictated by river geometry. The support can be provided by grounding or transfer of force to the riverbanks due to a river bend or cross-section constriction. When the ice has lodged (forming a jam) and is able to hold its position in equilibrium with the imposed forces, ice which arrives from upstream either extends the jam in the upstream direction or is incorporated in thickening the jam. The appearance of the Sullivan Creek jam just before lodgement is shown on Photograph 2.4. Significant increases in water level frequently occur upstream from a lodged ice jam. Eventually forces increase to the point where the jam releases. This often is related to simultaneously increasing discharge. The ice cover then moves to a downstream lodgement point and there is a rapid fall in upstream water levels.

The same locations often act as lodgement points year after year. Tables 2.1 and 2.2 list the lodgement locations which have been observed in the river reach from Grand Falls to Beechwood and from Beechwood to Mactaquac respectively. Figure 2.1 shows the location of these positions. Such individual lodgement locations may experience jamming in some years and not in other years, depending on the ice and river flow conditions. It is likely that under natural conditions a succession of locations also existed in the reaches flooded by the Beechwood and Mactaquac developments.

At the final lodgement position, each year, the forces are not great enough to overcome the resisting capability of the lodgement section. Then, over time, the ice mass erodes and melts or releases into open water and water levels fall to their open water values.

TABLE 2.1

GRAND FALLS TO BEECHWOOD REACH
ICE JAM LODGEMENT SITES

Jam Position Number	Approximate Location (miles upstream from Beechwood)	Observed Lodgement Locations 1987	Other Years
B1	24.4	Morrell Siding	Baker's Ferry
B2	17.6		Mouth of the Tobique River
B3	15.3		Perth Railroad Bridge
B4	13.3		Larlee Creek
B5	10.1		Between Kilburn and Inman
B5.1	7.9	Kilburn	Kilburn
B6	6.7	Muniac	Muniac
B7	4.3		Upper Kent Airfield
B8	3.7		Upstream of Upper Guisiguit Brook
B9	3.2	Upper Guisiguit Brook	Upper Guisiguit Brook
B10	2.8		Irving Piers

TABLE 2.2

BEECHWOOD TO MACTAQUAC REACH
ICE JAM LODGEMENT SITES

Jam Position Number	Approximate Location (miles upstream from Mactaquac)	Observed Lodgement Locations 1987	Other Years
M1	75.7		Green Island
M2	73.3	Bridge at Florenceville	Bridge at Florenceville
M3	72.4		Upstream from Buckwheat Bridge
M3.1	71.4	Buckwheat Bridge	Buckwheat Bridge
M4	70.3		Big Presque Isle
M5	65.1		Below Simonds
M6	60.4	Sproule's Island	Sproule's Island
M6.1	54.0	Pine Island	Pine Island
M6.2[1]	52.3	Indian Island Railroad Bridge	
M7	50.7		Grafton-Woodstock Bridge
M8	49.4	Island Park (Woodstock pumping station)	Island Park
M8.1[1]	48.9	Cozy Cabins	
M8.2[1]	46.4	Bulls Creek	
M9	44.4		Riordan
M10	38.8		Meductic
M11[1]	33.4	Sullivan Creek	

[1]Position newly recognized in 1987.

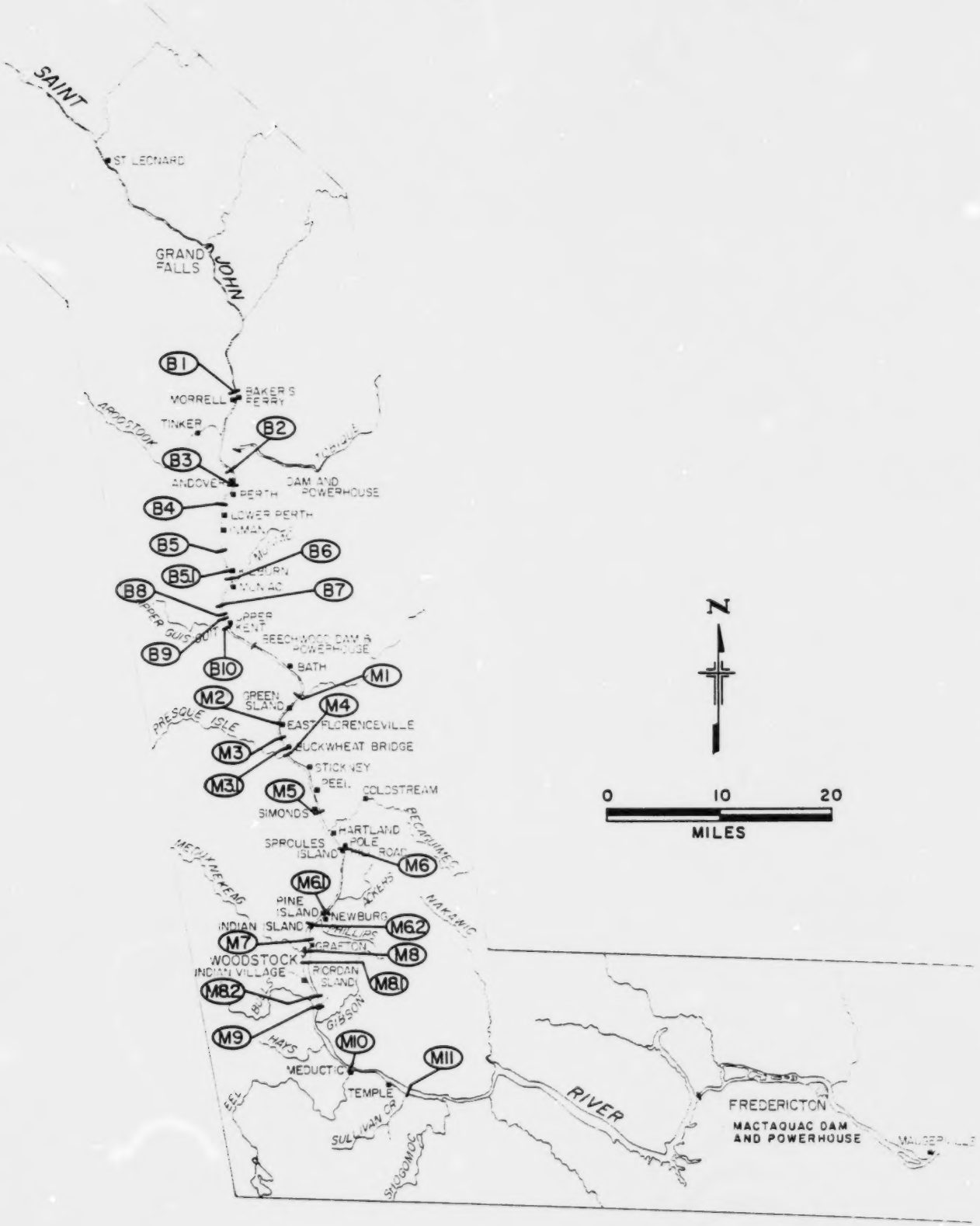


FIG. 2.1

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
1987 SAINT JOHN RIVER FLOODING

TYPICAL ICE JAM POSITIONS

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Normally this cycle of events takes place independently in the Grand Falls, Beechwood and Mactaquac reaches of the Saint John River. There usually is no passage of ice across the Beechwood and Mactaquac spillways and the corresponding reaches are effectively isolated. However, ice from above Grand Falls frequently passes downstream into the Beechwood headpond. In many years the ice is delayed above Grand Falls until any ice jam above Beechwood is well melted. The 1987 events were exceptional because ice from above Grand Falls moved down into the Beechwood headpond at a critical time. Later, this complete mass of ice moved through Beechwood into the Mactaquac headpond.

3 - CHRONOLOGY OF THE 1987 FLOOD EVENTS

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A general description of the events of late March and early April, 1987, is documented in this section. Section 3.1 acknowledges the source of data and observations. Many agencies and individuals contributed to the collection of the vast quantity of information used in this study. Section 3.2 describes the antecedent conditions, the progress of runoff in the basins, reservoir operations and water levels and the ice movements that occurred each day. Section 3.3 is a more comprehensive chronological description of events as they affected Perth-Andover, Simonds, Hartland, the Indian Island railroad bridge and the Woodstock area.

3.1 - Sources of Information

A great deal of data is routinely and continuously recorded along the Saint John River. The following information is routinely collected by the listed agencies.

(a) Weather - Environment Canada, Atmospheric Environment Service (AES)

(b) Snowpack - Saint John River Basin Cooperative Snow Survey prepared by the Saint John River Forecast Centre, Water Resource Planning, New Brunswick Department of Municipal Affairs and Environment. Nine agencies in New Brunswick, Quebec and the United States provide data for this snow survey.

(c) Water Levels and Discharges
- Water Survey of Canada
- The New Brunswick Electric Power Commission (NBEPC)

During ice jam periods, special observations and data are collected by a number of agencies. The following types of data were collected during the 1987 events by the listed agencies.

(a)	Ice Observations (jam locations, movements, etc)	- NBEPC - Department of Transportation - Acres International Limited - Emergency Measures Organization (EMO)
(b)	Special Surveys (high water marks, ice jam profiles, etc)	- NBEPC - Department of Transportation
(c)	Hydroelectric Plant Operating Records	- NBEPC

Appendix A contains a complete record of all available information for the period from March 30 to April 5. Table A.1 is for the Grand Falls to Beechwood reach, and Table A.2 is for the Beechwood to Mactaquac reach.

3.2 - General Description of the Events of Late March and Early April, 1987

3.2.1 - Antecedent Conditions

The initial state of the Saint John River basin at the start of the 1987 breakup is described by the following three factors.

(a) End-of-Winter Snow

The weather in the period from late fall 1986 until late winter 1987 was not unusual. The total winter precipitation

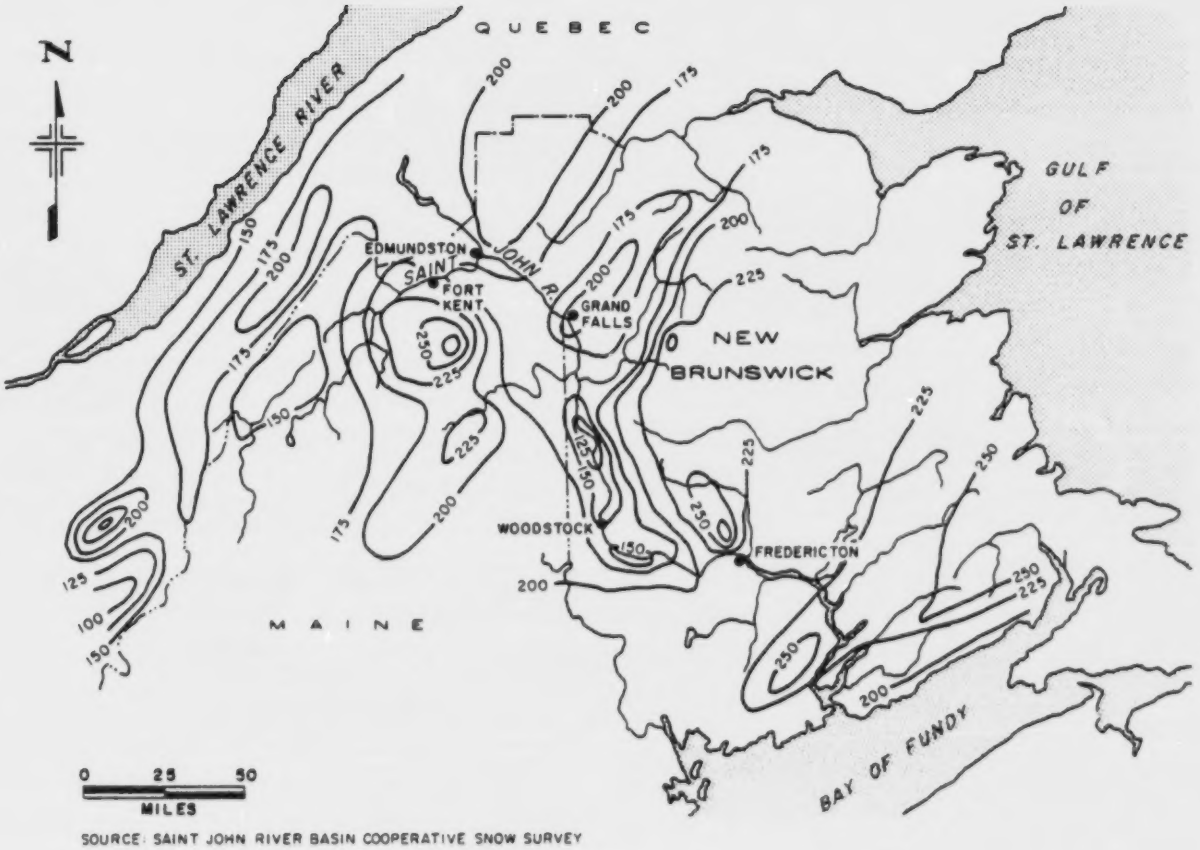
was approximately normal and temperatures were marginally lower than normal. The marginally lower temperatures resulted in more of the precipitation falling as snow and remaining as snowpack after it fell.

The lower half of the Saint John River basin, below Beechwood, had an average end-of-winter snowpack of 196 mm (7.7 in.) water equivalent. This amount of snowpack was, on average, 142% of normal. In some local parts of the basin the snowpack was twice the normal depth. The upper half of the basin, above Beechwood, had an average snowpack of 186 mm (7.3 in.) water equivalent, representing 91% of normal snowpack for that area. Figure 3.1 shows snowpack water equivalent isolines for March 18, just prior to initiation of snowmelt.

(b) Ice Cover

The total thickness of the ice cover consists of two components: blue ice resulting from thermal growth on the underside of the cover, and white ice resulting from consolidation of snow on the cover. The 1987 end-of-winter ice cover was not unusual. The Mactaquac headpond had an average of 23.5 inches of ice comprised of 13.5 inches of blue ice and 10 inches of white ice. The Beechwood and Grand Falls headponds had 21.7 and 22.3 inches of ice respectively. The average thickness for 29 years of record in the Beechwood headpond is 22.9 inches. The average thickness for 19 years of record in the Mactaquac headpond is 23.7 inches.

During the ice breakup period, observers noted that the ice cover broke up easily into relatively small pieces, suggesting that the ice was not unusually strong. This contrasts with the 1976 breakup when the ice was judged to be exceptionally strong.



SOURCE: SAINT JOHN RIVER BASIN COOPERATIVE SNOW SURVEY

FIG. 3.1

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
1987 SAINT JOHN RIVER FLOODING

SNOWPACK WATER EQUIVALENT ISOLINES (mm) ON MAR. 18, 1987

ACRES

(c) End-of-Winter River flows

The river flow just prior to breakup is determined by the rainfall and snowmelt occurring in the previous year, as well as snowmelt which occurred during the winter. It is not a major component in the spring discharge peak or in the discharge causing breakup. The 1987 end-of-winter flow was just over 3000 ft^3/s at Grand Falls.

3.2.2 - Progress of Runoff in the Basin

The temperature over the entire basin increased from about -5°C (23°F) to about +7°C (45°F) over the period from March 15 to March 22. The temperature remained above freezing after March 20. Approximately 50 - 60 Celsius degree-days (°C-days) of thawing[1] took place over the basin between March 20 and March 31. The uniform increase in temperature over the basin was partially responsible for the 50 - 75 mm (2 - 3 in.) of snowmelt that occurred. Figure 3.2 includes plots of temperature and accumulated thawing degree-days at the Beechwood Climatological Station for the period from mid-March to mid-April.

During the last 2 weeks of March an abnormal quantity of snow melted. The basin above Beechwood had snowmelt of 75 mm (3 in.) water equivalent. The normal snowmelt for this period is less than 2 mm (0.1 in.). The basin below Beechwood had snowmelt of 50 mm (2 in.) water equivalent, in comparison to a normal quantity of 16 mm (0.6 in.). These melt quantities, although abnormally large, were still much less than the available quantity of snow. Therefore, it can be concluded that the snowmelt

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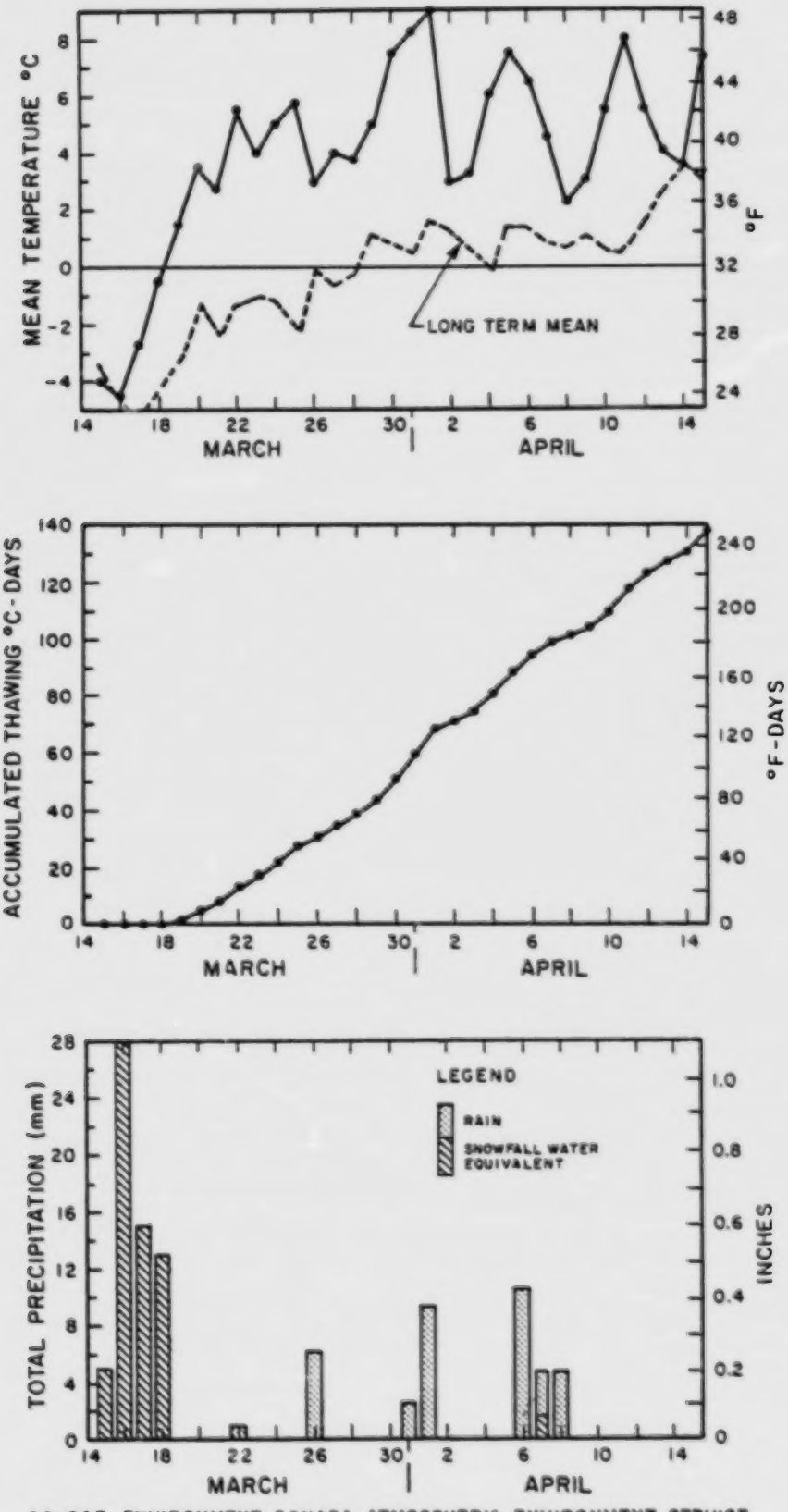
[1]A degree-day of thawing is a deviation of 1 degree above the freezing temperature for a 1-day period.



SOURCE: ENVIRONMENT CANADA ATMOSPHERIC ENVIRONMENT SERVICE

FIG. 3.2

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
1987 SAINT JOHN RIVER FLOODING
BEECHWOOD CLIMATOLOGICAL DATA

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contribution to increased discharge was primarily a result of the melt rate over the basin rather than the absolute snow quantity.

An examination of records for six meteorologic stations along the Saint John River shows that the total precipitation (rain plus water equivalent of snowfall) during the period from March 19 to April 1 ranged from 15 - 28 mm (0.6 - 1.1 in.). During April 2, 3 and 4 no additional precipitation fell. Figure 3.2 includes a plot of precipitation at the Beechwood Climatological Station for the period from mid-March to mid-April. The precipitation from March 15 to March 18 fell as snow and is included in the March 18 snowpack isolines shown in Figure 3.1.

The total water input to the basin over the last 2 weeks of March (March 19 to April 1) was approximately 95 mm (3.8 in.) water equivalent for the portion of the basin above Beechwood and 70 mm (2.8 in.) water equivalent for the portion of the basin below Beechwood. The portion of the basin above Beechwood had about 75 mm (3 in.) of snowmelt combined with about 20 mm (0.8 in.) of precipitation. The portion of the basin below Beechwood had about 50 mm (2 in.) of snowmelt combined with about 20 mm (0.8 in.) of precipitation. These total water inputs were responsible for the abnormally large breakup discharge in the Saint John River. When such a large breakup discharge occurs in late winter, as occurred in 1987, it can result in significant ice jam problems.

Plate 1 is a map of the Saint John River showing river flow hydrographs during the period March 30 to April 5. The hydrographs all started to rise noticeably on March 31 and they peaked on April 2 or very early on April 3. The Beechwood and Mactaquac inflows were estimated using the 1-dimensional Synthesized Open Channel Hydraulics (SOCH) computer model. This model combines upstream flow values, and routes them downriver to a particular point of interest. The estimated inflows do not consider ice jam

storage and release dynamics, and consequently are only an estimate of inflows at any particular time. This estimated inflow represents the inflow that would occur in the absence of storage behind ice jams, and the inflow calculated hour by hour may, in fact, not actually reach the reservoir in the same time frame. These SOCH inflow estimates were not available to the operators at the time operational decisions were being made.

3.2.3 - Reservoir Operations and Water Levels

In response to naturally increasing river flows and consequent higher river stages, the headponds of the hydro plants along the Saint John River were operated in accordance with guidelines that have evolved over many years. The guidelines generally call for gradual drawdown of the headponds as the river flows increase.

Flow forecasts for the Saint John River and its tributaries are provided to NBEPC during the spring runoff period by the Saint John River Flow Forecast Centre (FFC). Using these forecasted river flows, hour-by-hour headpond operation schedules are drawn up in coordination with the FFC. Gauges on the Saint John River and its tributaries are continuously monitored during the critical period by the hydro plant staff, and the headpond operations are revised if the actual river flows deviate from the forecasted values. Plate 2 shows water level hydrographs at the hydro plants as well as several points of interest.

The following paragraphs present a description of the Saint John River headpond operations during the 1987 ice jam period.

(a) Grand Falls

The Grand Falls development is a run-of-river hydroelectric plant which exploits a natural waterfall. The gated

spillway regulates the flow of water over the falls for a narrow range of headpond levels and natural river flows.

By March 20, the river flow exceeded the discharge capacity of the generating station and water was being passed through the spillway gates. Starting at 09:00, April 1, the headpond was gradually drawn down until it reached el 423.25 ft at 18:00. At 20:00, April 1, all eleven gates were wide open and clear of the water surface. As the inflows continued to increase, the headpond levels rose--with all gates still wide open. Ice started to spill through the gates at 20:00, April 1 and the ice spillage continued until 11:00, April 2. The gates all remained fully open through midnight of April 5.

(b) Beechwood

The approach to operating the Beechwood dam is to draw down the reservoir as the river flow increases so as to maintain near natural water levels at Perth-Andover.

In 1987 a modest amount of water was spilled starting at 08:30, March 30. Beginning at 12:00, March 31, in response to increasing inflows, gate openings were progressively increased. The headpond was held at about el 242.0 ft until 24:00, March 31. In response to the first rapid rise in elevation at Perth-Andover at about midnight, March 31, actions to draw down the headpond began.

In the first half of April 1, ice jams worked their way downstream until a lodgement occurred at Upper Guisiguit Brook at about 13:00. These ice movements were accompanied by fluctuations in water level at Perth-Andover and at Beechwood dam.

Progressive opening of gates, in response to increasing flows and rising levels at Perth-Andover, began in earnest at 10:00, April 1, and continued into April 2. At 10:00, April 1, seven sluice gates were open 8 feet, and two were open 4 feet. By 24:00, April 1, seven sluice gates were open 11 feet, one was open 6 feet and one was open 4 feet. At 00:30, April 2, a major drawdown was started at Beechwood, and by 04:00 eight gates were open 15 feet and one was open 4 feet. At 06:00 three gates were clear of the water surface; at 07:00 four gates were clear, and at 08:00 five gates were clear. A sixth gate was raised clear of the water surface by 10:00.

As a result of the gate operations, the water level at the dam fell to 232.8 ft at 07:45, April 2. In spite of this drawdown, the Perth-Andover levels continued to rise because water was held behind the Upper Guisiguit Brook ice jam. The Upper Guisiguit Brook ice jam was reported to release at about 09:30. The water level at the dam started to increase rapidly at 09:35 and ice was being passed through the spillway by 09:55, April 2. By 10:15 the level reached el 243.0 ft. All ice had passed through Beechwood at 14:00, April 2, and four gates were closed. The headpond gradually fell to el 234.2 ft at 16:00, April 3. As the inflow dropped, very gradual gate operations slowly brought the headpond to el 238.8 ft at 14:00, April 5.

(c) Mactaquac

Mactaquac is the largest reservoir on the Saint John River. The Mactaquac project therefore has somewhat greater flexibility in operation than either Beechwood or Grand Falls. The implications of operation on both upstream and downstream locations must be carefully considered. All spillway operations are coordinated with the FFC.

Spilling operations began with four of ten sluice gates at 12:00, March 31. At this time the water level at the dam began to be reduced below that at Woodstock. At 01:00, April 1, the water level at the dam was 128.1 ft and operations started with six gates partially open. By 15:00, April 1, the water level at the dam was 127.4 ft and nine gates were in operation. The level was drawn down to just under 124.0 ft by late on April 2, and it fluctuated just below el 124.0 ft during April 3, 4 and part of April 5.

Reservoirs were also operated on two tributaries. Operations on the Tobique and Aroostook rivers are described below.

(a) Tobique

The Tobique spillway started spilling through its single regulating gate at 08:15, March 31. The first of four sluice gates was opened at 16:30, March 31. Spillway operations gradually increased, with the objective of maintaining a maximum elevation of 313.5 ft in the headpond. At about 03:00, April 2, a small and gradual headpond drawdown was initiated. The level dropped to el 309.8 ft at 12:00, April 2. Subsequent operations gradually returned the reservoir to el 311.8 ft with inflow matching outflow. The Tobique spillway did not spill any ice into the Saint John River.

(b) Aroostook

The Tinker dam on the Aroostook River is operated by the Maine Public Service. Tinker began spilling water at 18:00, March 29. At 17:00, April 1, Aroostook River ice started to spill.

3.2.4 - Ice Movements

Plate 3 is a map summarizing the chronology of 1987 breakup events along the Saint John River. Ice movements, jam locations and operations are all summarized, by location, in this figure. A brief day-by-day summary is presented below.

March 27 - March 29

During this period the discharge began to gradually increase and open water was observed downstream from each dam for the following distances

- 2.5 miles below Grand Falls
- 0.6 miles below Tinker (on the Aroostook River)
- 4.0 miles below Beechwood (ice was at Bath).

Late on March 29 the Tinker dam started to spill water.

March 30

The ice above Grand Falls started to move. There was continuous ice from Grand Falls upstream to Green River, and then 2.5 miles of broken ice towards St. Basile. From St. Basile upstream, the river was open, and then there was 17 miles of broken ice from St. Francis to Dickey, Maine.

The ice below Grand Falls started to break up. The open water extended 4 miles from Grand Falls, followed by 0.6 miles of broken ice, followed by thermal ice down to Beechwood.

Beechwood started spilling at 08:30 and the downstream ice started to move. Small jams lodged successively at the Trans-Canada Highway Bridge in Florenceville and then at Buckwheat Bridge. Figure 3.3 shows the location and length of these two

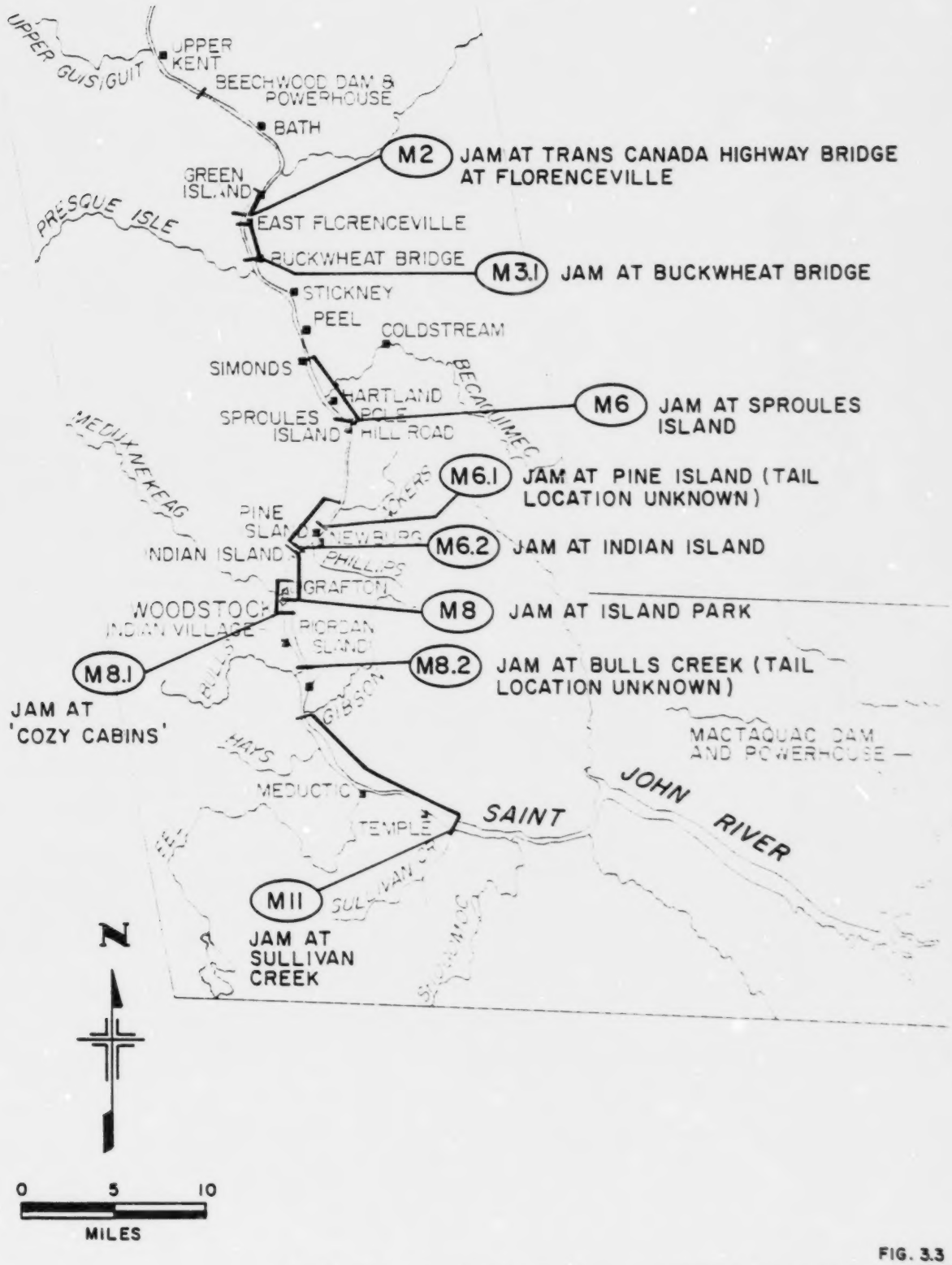


FIG. 3.3

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
1987 SAINT JOHN RIVER FLOODING

ICE JAM LOCATIONS IN THE BEECHWOOD TO MACTAQUAC REACH

ACRES

ice jams. The ice in the Big Presque Isle and Becaguimec streams had already run into the Saint John River.

March 31

All of the ice above Green River started to move. A jam was observed at Green River early in the day and it gradually moved downstream toward Ste. Anne. All of the upstream ice accumulated in this part of the river, creating an ice jam about 12 miles long.

The ice between Grand Falls and Perth-Andover started to move. By 10:00 the river was open 12 miles downstream from Grand Falls followed by 9 miles of alternating broken ice and open water. The Tobique River had started spilling and an open lead had developed from the Tobique powerhouse tailrace to the Perth-Andover Bridge. At 16:00 a small jam was located in the Baker's Ferry/Morrell area above Perth-Andover. Figure 3.4 shows the location and extent of this small ice jam. This jam flooded the road at Baker's Ferry. By midnight the jam had released and broken ice was moving through Perth-Andover.

Shortly after noon the jam at Buckwheat Bridge started to move down through Simonds and Hartland. A jam was observed at Sproule's Island at 18:40 (see Figure 3.3). Photograph 3.1 shows the head of this jam. Shortly after 18:40 the road in Simonds was closed. Just before midnight the Sproule's Island jam shoved (or consolidated) and levels in Hartland dropped. The Simonds levels did not drop--suggesting that a secondary jam was located between Hartland and Simonds (possibly at Upper Becaguimec Island).

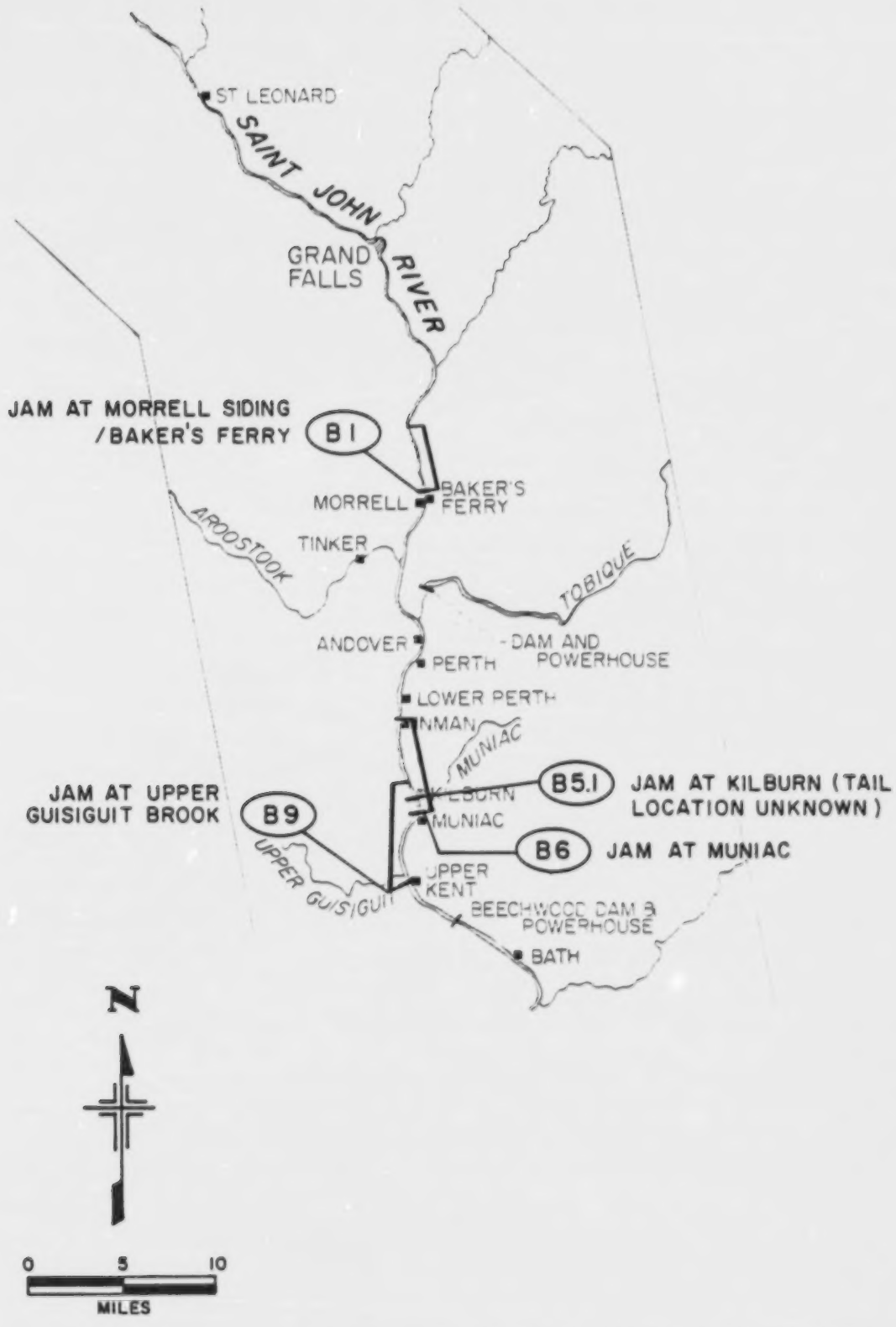


FIG. 3.4

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
1987 SAINT JOHN RIVER FLOODING

ICE JAM LOCATIONS IN THE GRAND FALLS TO BEECHWOOD REACH

ACRES

PHOTOGRAPH 3.1 **SPROULE'S ISLAND ICE JAM**
LOCATION: SPROULE'S ISLAND
TIME/DATE: 17:15 - MARCH 31, 1987

PHOTOGRAPH 3.2 **UPPER QUISIGUIT BROOK ICE JAM LODGEMENT**
LOCATION: UPPER KENT
TIME/DATE: 13:25 - APRIL 1, 1987

April 1

The ice jam above Grand Falls was lodged just upstream from St. Leonard at 10:00. By 20:00 the jam had dislodged and there was broken ice all the way to Grand Falls. Ice started to pass through the Grand Falls spillway at this time.

The ice ran through Perth-Andover late March 31 and was observed in a jam at Muniac at 08:45 (see Figure 3.4). Throughout the day successive jams worked their way downstream until a lodgement occurred near Upper Guisiguit Brook at about 13:00 (see Figure 3.4). Photograph 3.2 shows the jam lodgement at this location. A full description of these ice movements and their effects can be found in Section 3.3.1.

Very early in the morning (01:20) the Sproule's Island jam released and moved downstream to Pine Island. The jam held for a brief period at Pine Island before moving down to lodge at Indian Island (see Figure 3.3). The lodgement was in the west channel at the Indian Island railroad bridge and diverted a large portion of the flow to the east channel. This abnormally large flow in the east channel resulted in high velocities that undermined a pier and an abutment. Shortly after 11:00 two spans of the bridge over the east channel collapsed. The ice that released from this jam moved through the east channel and worked its way down through Woodstock to a lodgement just downstream from the town (see Figure 3.3). Section 3.3.2 provides a more extensive description of events in this reach of the river.

April 2

Grand Falls continued to spill ice continuously until 11:00. Small quantities of ice were spilled periodically throughout the rest of the day.

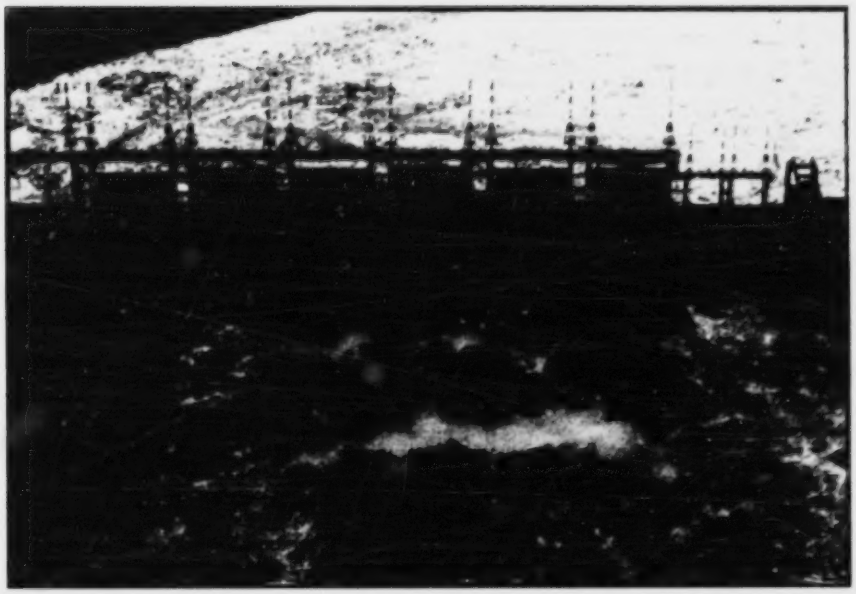
Water was over the road at lower Perth at 00:15. A major drawdown was started at the Beechwood plant at 00:30. The level in Perth-Andover continued to rise. Between 05:00 and 06:00, the Perth-Andover railroad bridge started to trap ice arriving from Grand Falls. The bridge failed at about 09:00 when all 5 spans and 17 loaded railcars were pushed into the river. Perth-Andover experienced serious flooding throughout this period and maximum levels of about 260.0 ft (measured by the New Brunswick Department of Transportation) were reached at about the time of the bridge failure. The Upper Guisiguit Brook ice jam was reported to release at about 09:30. All of the ice from this jam (including ice from above Grand Falls) had passed through the Beechwood spillway by 14:00. Photograph 3.3 shows the ice passing through the Beechwood spillway. By midnight the water level in Perth had receded to less than 252 ft.

The jam just below Woodstock moved to near Bulls Creek during the early morning hours (see Figure 3.3). At 13:45 this jam released, and by 16:35 it was observed moving at about 1 ft/s near Sullivan Creek. The ice from above Beechwood was arriving at the tail of the jam at this time. Photograph 3.4 shows the mass of broken ice from the Upper Guisiguit Brook jam passing by Florenceville.

April 3

At 08:30 the jam was located at Sullivan Creek with its tail at about Gibson Millstream (see Figure 3.3). Upstream from Gibson Millstream the river was essentially open. However, small quantities of shore ice continued to be dislodged and carried downstream to the tail of the jam.

Photograph 2.4 in Section 2 shows the Sullivan Creek jam lodgement. The tail of the jam was at the Gibson Millstream Church.



PHOTOGRAPH 3.3 **ICE PASSING THROUGH BEECHWOOD CONTROL STRUCTURE**
LOCATION: BEECHWOOD
TIME/DATE: 11:00 - APRIL 2, 1987

PHOTOGRAPH 3.4 **ICE FROM UPPER GUISIGUIT BROOK JAM PASSING BY FLORENCEVILLE**
LOCATION: FLORENCEVILLE
TIME/DATE: 14:10 - APRIL 2, 1987

The maximum stage of 143.9 ft in Woodstock was reached between 19:00 and 20:00. As the flow dropped and the jam slowly deteriorated, the water level at Woodstock subsided.

3.3 - Detailed Chronology of Events

This section presents a comprehensive description of events as they affect locations of interest--in the Grand Falls to Beechwood and Beechwood to Mactaquac reaches. The information is arranged to explain events in the context of location, rather than by date as in Section 3.2. Therefore, some of the information presented in Section 3.2 is repeated.

3.3.1 - Chronology of Events in the Grand Falls to Beechwood Reach

Figure 3.5 shows an estimated Beechwood headpond inflow hydrograph. Figures 3.6 and 3.7 are time history plots of Perth-Andover water levels and Beechwood headpond water levels at the dam. The main features of the Perth-Andover flooding are shown in these figures. The event chronology is discussed in more detail below.

(a) Flow Conditions

The drainage area above Perth-Andover is about 1% less than the drainage area above Beechwood and, therefore, during normal open water circumstances, the Perth-Andover flows are effectively identical to the Beechwood inflows. Figure 3.5 shows the estimated Beechwood inflow hydrograph.

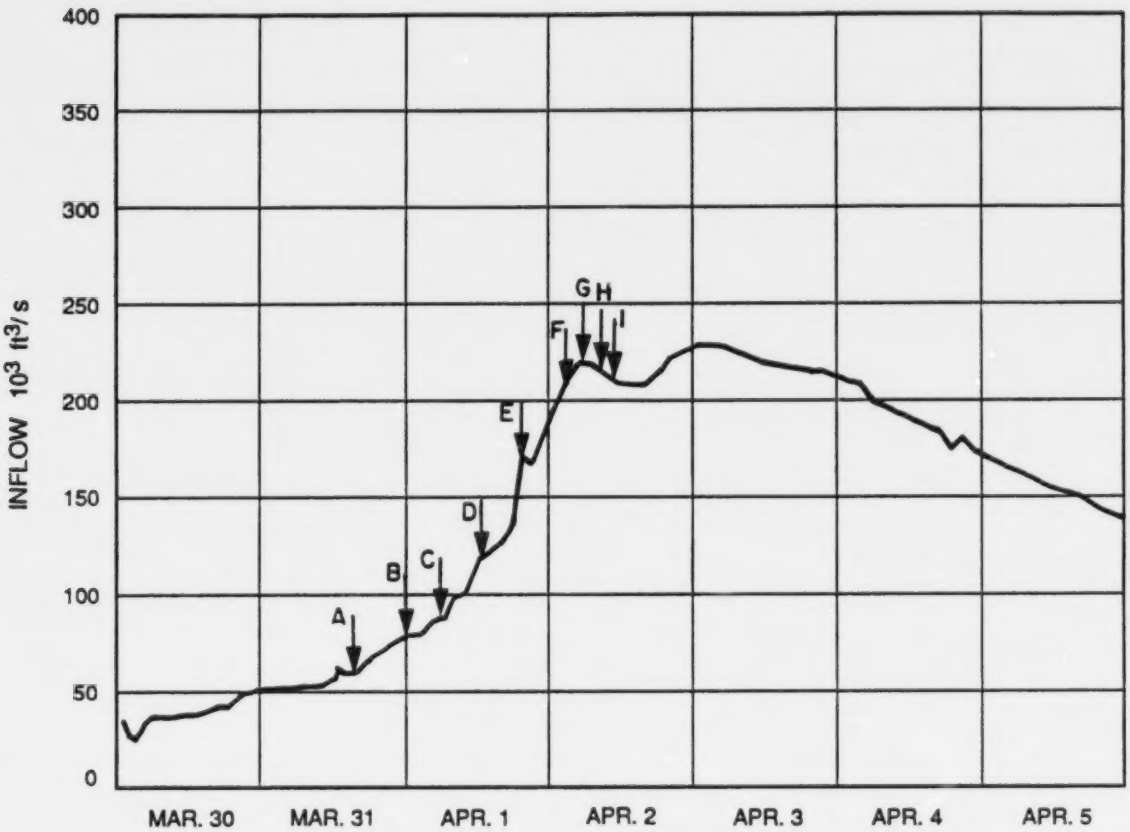
The Beechwood inflows were estimated using the 'SOCH' computer model. This model takes upstream flows and routes them down the river to a particular point of interest. The

estimated Beechwood inflows at the dam do not consider jam storage and release dynamics and consequently are only an estimate of inflows at any particular time. The estimated inflow represents the inflow that would occur in the absence of storage behind ice jams, and the 'inflow', calculated hour by hour, may in fact not actually reach the reservoir in the same time frame.

Figure 3.5 shows that the Saint John River was carrying less than 50 000 ft^3/s until midnight, March 30. In response to meteorologic conditions, which caused snowmelt and precipitation, the inflow slowly increased to about 80 000 ft^3/s by midnight, March 31. This inflow was sufficient to break the thermal ice and carry it through Perth-Andover to downstream lodgement locations. During April 1, the inflow increased steadily to about 190 000 ft^3/s. The inflow then fluctuated between 200 000 and 225 000 ft^3/s for most of April 2 and 3, before slowly receding to about 140 000 ft^3/s by midnight, April 5.

(b) Jam Locations/Movements and Water Levels

On March 31 a small jam formed in the Baker's Ferry/Morrell area above Perth-Andover. About midnight this jam released and moved downstream through Perth-Andover. The water level at the Perth gauge rose from about 243 ft at midnight to 252.8 ft at 04:45, April 1. As the jam moved downstream the level slowly subsided. At 12:00 the jam was moving past Upper Kent airfield (see Photograph 2.3). At about 13:00 the jam was observed in its final Upper Guisiguit Brook position. Perth-Andover levels fluctuated near 247.5 ft until 19:00. Tinker dam started spilling Aroostook River ice at 17:00. This ice was observed passing through Perth-Andover at 19:00. The Perth-Andover levels began to rise again. At 23:30 the Upper Guisiguit Brook jam underwent



A - JAM FORMED IN MORRELL AREA
B - ICE MOVING THROUGH PERTH-ANDOVER
C - JAM OBSERVED AT KILBURN
D - JAM AT UPPER GUISIGUIT BROOK
E - AROOSTOOK RIVER ICE MOVING THROUGH PERTH-ANDOVER
F - GRAND FALLS ICE ARRIVING AT TAIL OF JAM
G - PERTH-ANDOVER RAILROAD BRIDGE STOPPING ICE - BRIDGE REPORTED MOVED
H - RAILROAD BRIDGE IN RIVER - UPPER GUISIGUIT BROOK JAM RELEASED WITHIN THE NEXT 30 MINUTES
I - ICE STARTED TO PASS BEECHWOOD

NOTE:
INFLOW ESTIMATED USING THE "SOCH" MODEL

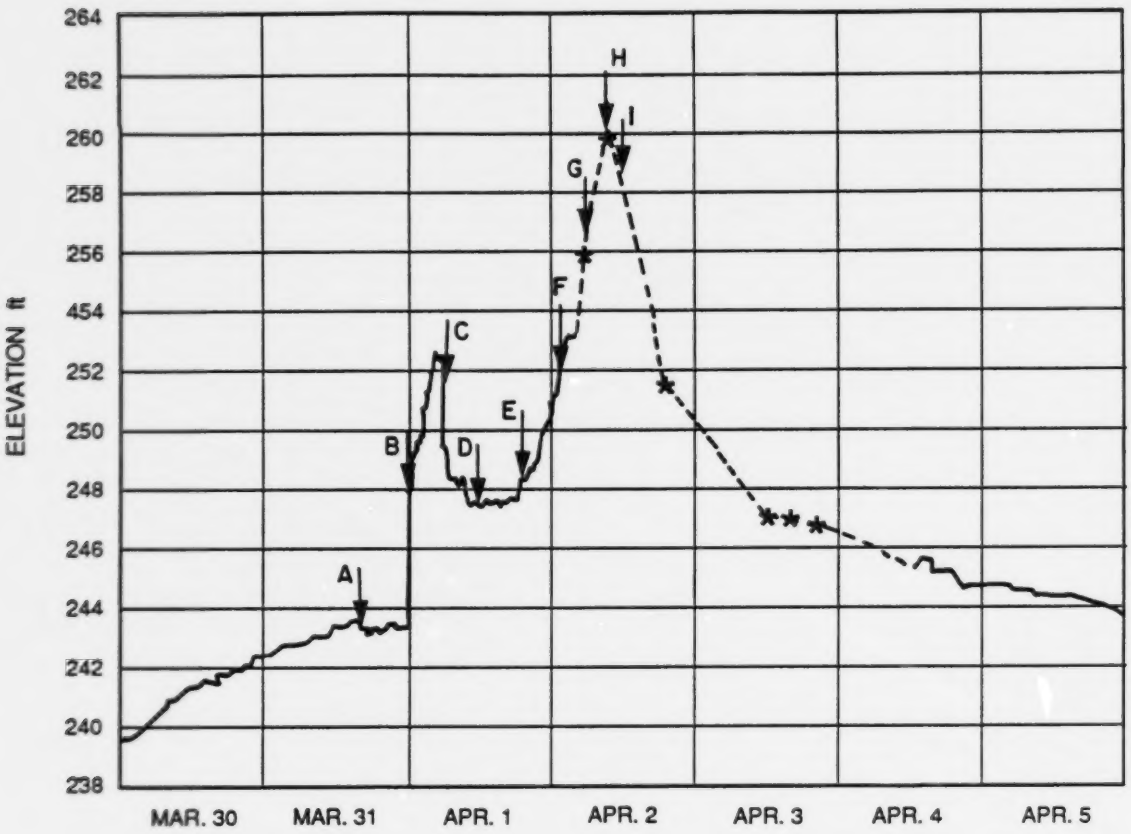
Fig. 3.5

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
1987 SAINT JOHN RIVER FLOODING
ESTIMATED BEECHWOOD INFLOW

ACRES

further consolidation. Photograph 3.2 shows the head of the Upper Guisiguit Brook ice jam just after lodgement. Earlier, at 20:00, the Grand Falls dam started to spill Saint John River ice. This ice began arriving at the tail of the Upper Guisiguit Brook jam at 02:00, April 2. The Perth-Andover water level continued to rise. The Perth gauge stopped operating at 04:00 when the level was 252.8 ft and levels shown in Figure 3.6 after this time are based upon other data. At 05:00, ice was reported passing beneath the Perth-Andover railroad bridge. By 06:00, ice was being stopped by the lower chord of the bridge (el 256.0 ft). The bridge was reported to move at this time. Grand Falls ice continued to arrive at Perth-Andover and deposit behind the railroad bridge jam. This jam reached an ultimate length of 1200 to 1500 feet before the bridge failed at 09:00. Photograph 3.5 shows the water level on the downstream side of the bridge at about the rail level (el 259.2 ft) just prior to failure of the bridge. Photographs 3.6 to 3.8 show the progressive failure of the railroad bridge. (The bridge, visible in Photograph 3.8, is the downstream highway bridge--the railroad bridge has failed.) When the bridge failed, the Perth-Andover levels surged upwards to 260.1 ft at a location just downstream of the bridge. Maximum levels above the bridge were higher and occurred just after the bridge failed. The high water elevations were surveyed by the New Brunswick Department of Transportation. Relevant peak water levels are as follows.

Location Relative to Railroad Bridge	Water Level (ft)
-1700 ft downstream	260.1
-3000 ft upstream	260.7
-1.5 miles upstream	262.3
-2 miles upstream (Tobique tailrace gauge)	263.0



A - JAM FORMED IN MORRELL AREA
B - ICE MOVING THROUGH PERTH-ANDOVER
C - JAM OBSERVED AT KILBURN
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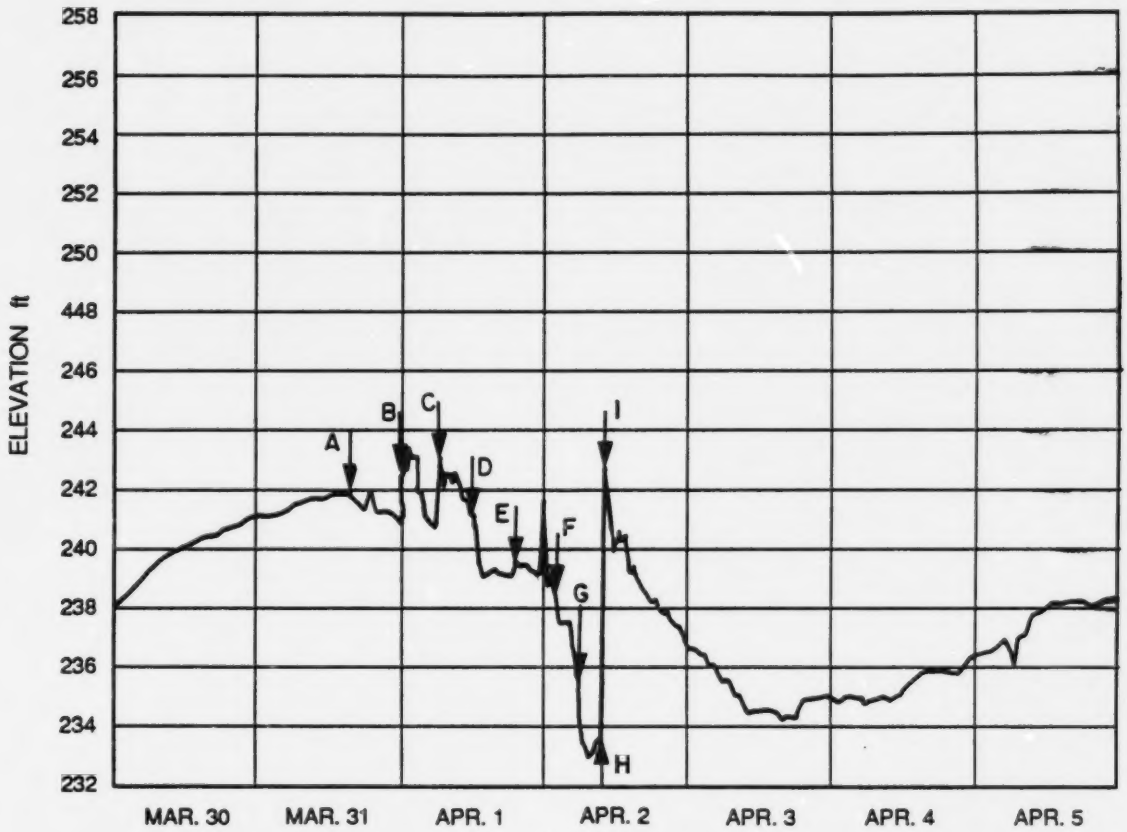
H - RAILROAD BRIDGE IN RIVER - UPPER GUISIGUIT BROOK JAM RELEASED WITHIN THE NEXT 30 MINUTES
I - ICE STARTED TO PASS BEECHWOOD

NOTE:
* ARE SPOT ELEVATION MEASUREMENTS TAKEN WHILE THE GAUGE WAS NOT OPERATING

Fig. 3.6

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
1987 SAINT JOHN RIVER FLOODING
WATER LEVELS AT PERTH-ANDOVER

ACRES



A - JAM FORMED IN MORRELL AREA
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H - RAILROAD BRIDGE IN RIVER - UPPER GUISIGUIT BROOK JAM RELEASED WITHIN THE NEXT 30 MINUTES
I - ICE STARTED TO PASS BEECHWOOD

Fig. 3.7

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
1987 SAINT JOHN RIVER FLOODING
WATER LEVELS IN BEECHWOOD HEADPOND

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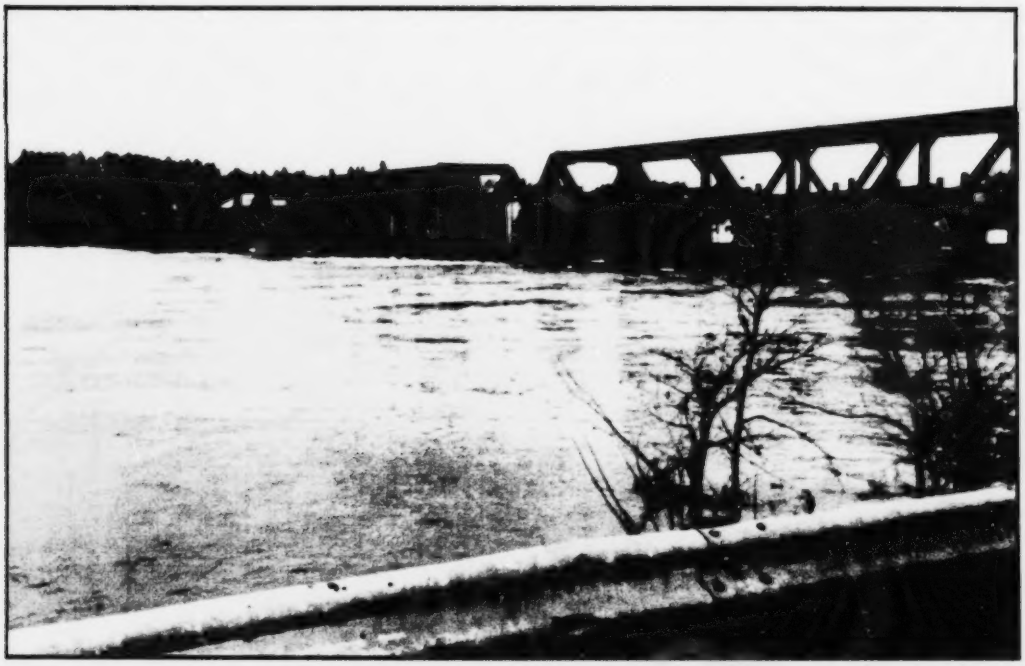
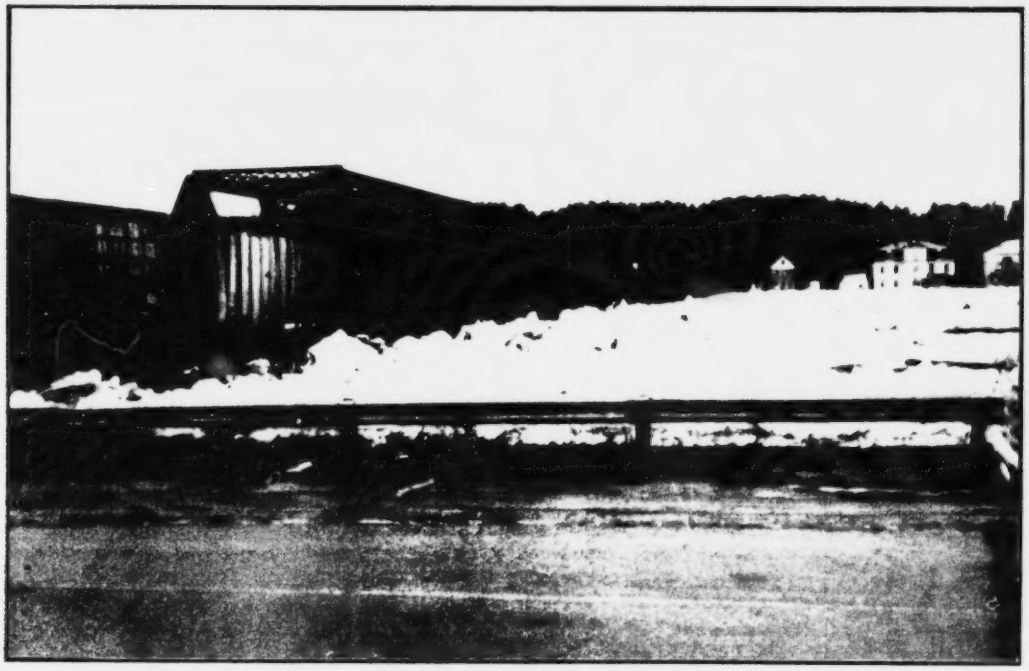


PHOTOGRAPH 3.5 **DOWNSTREAM SIDE OF PERTH-ANDOVER RAILROAD BRIDGE JUST PRIOR TO FAILURE**
LOCATION: PERTH-ANDOVER
TIME/DATE: ~8:00 TO 9:00 - APRIL 2, 1987



PHOTOGRAPH 3.6 **UPSTREAM SIDE OF PERTH-ANDOVER RAILROAD BRIDGE JUST PRIOR TO FAILURE**
LOCATION: PERTH-ANDOVER
TIME/DATE: ~9:00 - APRIL 2, 1987

PHOTOGRAPH 3.7 **INITIAL STAGES OF PERTH-ANDOVER RAILROAD BRIDGE FAILURE**
LOCATION: PERTH-ANDOVER
TIME/DATE: 9:00 - APRIL 2, 1987

PHOTOGRAPH 3.8 **FINAL STAGES OF PERTH-ANDOVER RAILROAD BRIDGE FAILURE**
LOCATION: PERTH-ANDOVER
TIME DATE: 9:00 - APRIL 2, 1987

The Upper Guisiguit Brook ice jam was reported to release at about 09:30, April 2. By 09:55 ice was being passed through the Beechwood spillway. Water levels in Perth-Andover began to subside and reached el 251.6 ft at 19:00. By 12:00, April 3 the Perth-Andover level had fallen below 247 ft.

3.3.2 - Chronology of Events in the Beechwood to Mactaquac Reach

Figures 3.8 and 3.9 show hydrographs of Beechwood outflow and estimated inflow to the Mactaquac headpond at the dam. Figure 3.10 shows time history plots of water levels at Simonds, Hartland, Woodstock and Mactaquac headpond at the dam. The main events in the Simonds to Woodstock reach are shown in these figures. The event chronology is discussed in more detail below.

(a) Flow Conditions

Figure 3.8 shows the outflow from the Beechwood development --turbine and spillway flows are included. Figure 3.9 is an estimate of Mactaquac headpond inflow. Because of jam storage and release dynamics, the inflow can only be estimated. The estimated inflow represents the inflow that would occur in the absence of storage behind ice jams and the 'inflow' may in fact not actually reach the reservoir in the precise time period for which it is calculated.

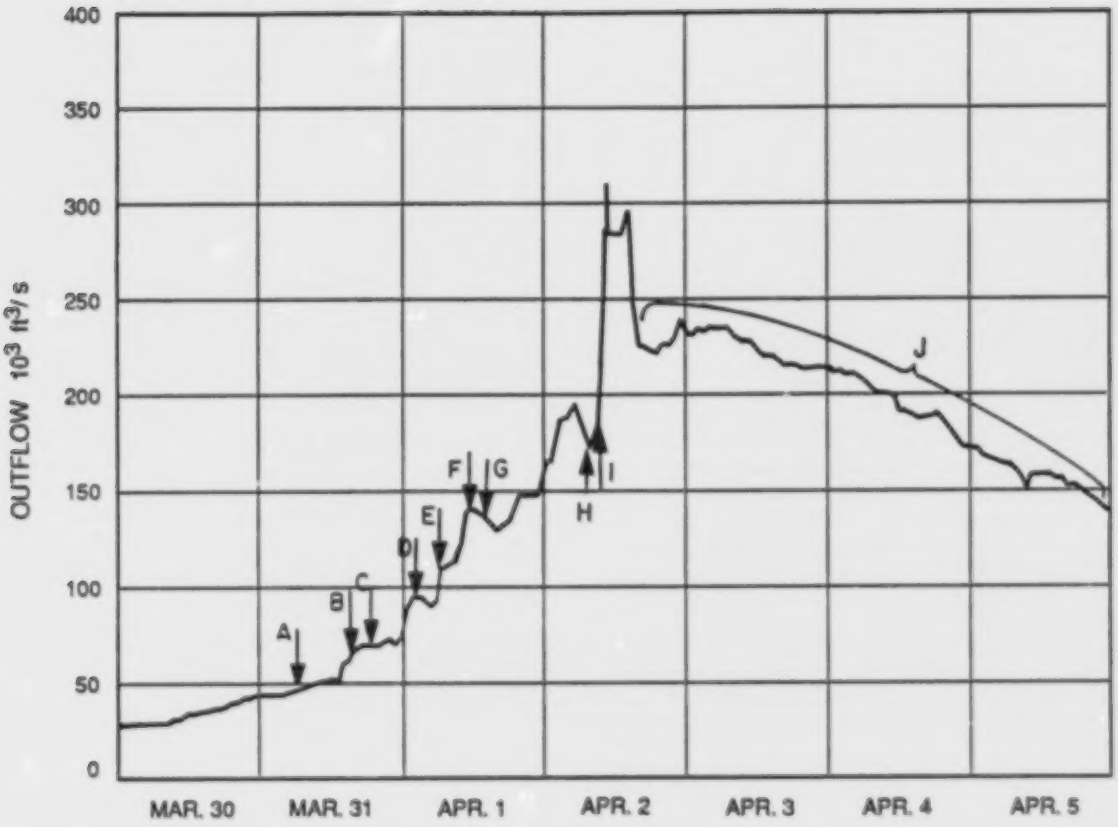
The Beechwood outflow was less than 50 000 ft^3/s until midnight, March 30. In response to meteorologic conditions, which caused snowmelt and precipitation, the flow slowly increased to about 80 000 ft^3/s outflow from Beechwood and 105 000 ft^3/s inflow to Mactaquac at midnight, March 31. This flow was sufficient to break the thermal ice cover between Beechwood and Hartland and to initiate successive jams at Sproule's and Pine islands. During April 1 the

discharge increased steadily to 165 000 ft^3/s at Beechwood (outflow) and 215 000 ft^3/s at Mactaquac (inflow). Shortly after dislodgement of the Upper Guisiguit Brook ice jam, the Beechwood outflow peaked at 310 000 ft^3/s (10:30). The estimated inflow to Mactaquac peaked 5.5 hours later (16:00) at 341 000 ft^3/s. By midnight, April 2, the Beechwood outflow was 232 000 ft^3/s. The Mactaquac inflow at midnight, April 2, was 290 000 ft^3/s. The flow gradually dropped over the next 3 days until the Beechwood outflow was 138 000 ft^3/s and the Mactaquac inflow was 162 000 ft^3/s at midnight, April 5.

(b) Jam Locations/Movements and Water Levels

Details of jam locations/movements and associated water levels are discussed below for Simonds, Hartland, the Indian Island railroad bridge and Woodstock. The relationships between the water levels and various events are summarized in Figure 3.10. The water level record at each of these sites is explained, and therefore the same jam is discussed in several sections (i.e. the Sproule's Island jam affected both Hartland and Simonds).

(i) Simonds - On March 31 at 06:00, a small jam was located at Peel Island approximately 0.6 miles above the Simonds gauge. By 15:45 ice was observed moving through Simonds and the level started to increase above 150.0 ft to 156.9 ft at 17:00. At 18:40 a jam was observed at Sproule's Island with its tail at Simonds. Water reached the road in Simonds at this time. Forty minutes later, at 19:20, water was over the road, and at 20:15 the road was closed. At 21:35, ice started to move at the Hartland covered bridge. Figure 3.10 shows that the Hartland gauge level dropped about 5 feet during this movement while

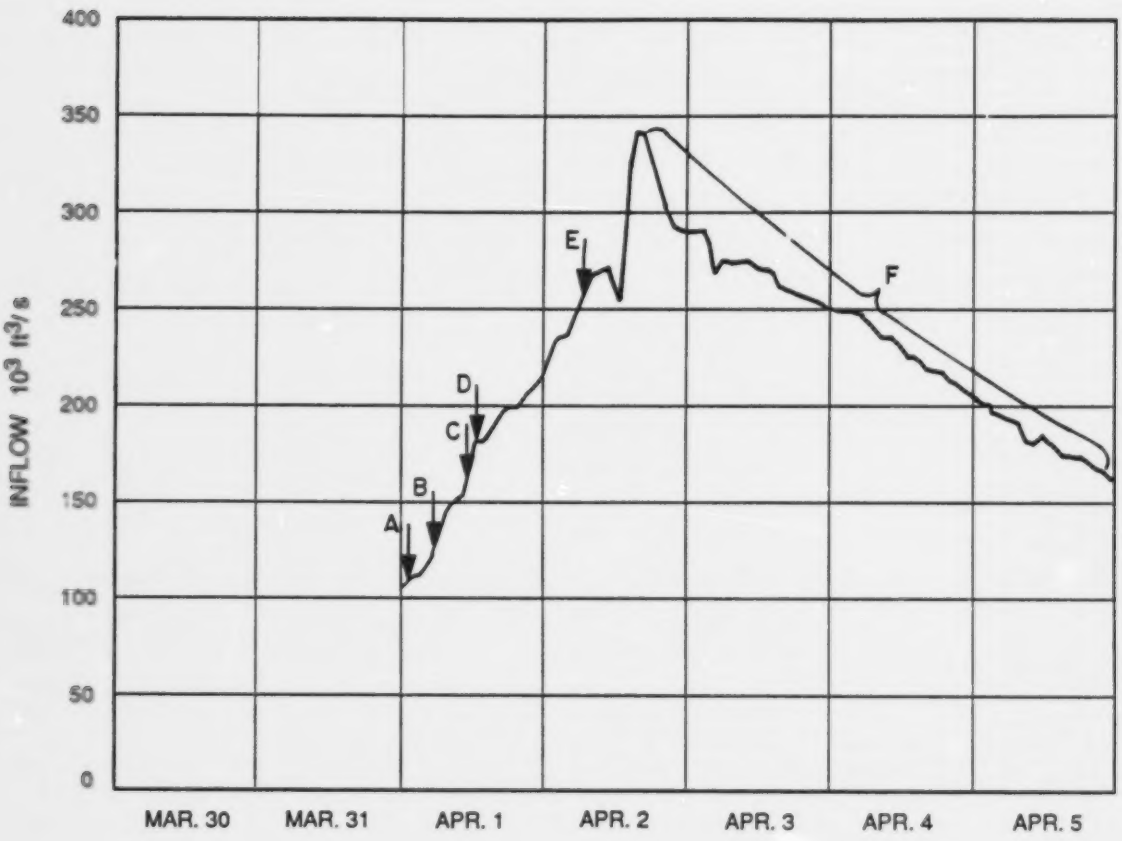


A - SMALL JAM 0.6 MILES ABOVE SIMONDS
B - ICE MOVING THROUGH SIMONDS AND THEN HARTLAND
C - JAM AT SPROULE'S ISLAND
D - JAM AT PINE ISLAND
E - JAM IN WEST CHANNEL AT INDIAN ISLAND RAILROAD BRIDGE
F - RAILROAD BRIDGE FAILED AND ICE MOVED DOWNSTREAM
G - JAM AT WOODSTOCK PUMPING STATION
H - JAM AT BULLS CREEK
I - UPPER GUISIGUIT BROOK JAM RELEASED
J - JAM LOCATED AT SULLIVAN CREEK

Fig. 3.8

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
1987 SAINT JOHN RIVER FLOODING
BEECHWOOD OUTFLOW

ACRES



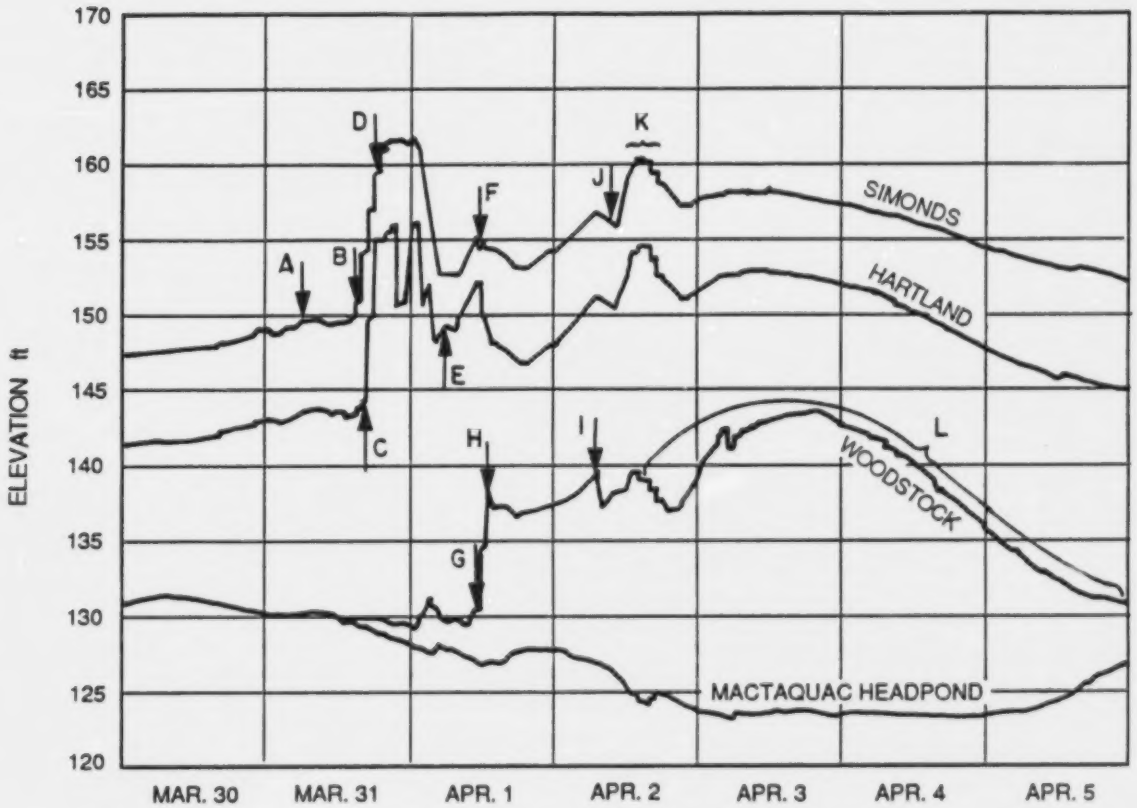
A - JAM AT PINE ISLAND
B - JAM IN WEST CHANNEL AT INDIAN ISLAND RAILROAD BRIDGE
C - RAILROAD BRIDGE FAILED AND ICE MOVED DOWNSTREAM
D - JAM AT WOODSTOCK PUMPING STATION
E - JAM AT BULLS CREEK
F - JAM LOCATED AT SULLIVAN CREEK

NOTE:
INFLOW ESTIMATED USING THE "SOCH" MODEL

Fig. 3.9

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
1987 SAINT JOHN RIVER FLOODING
ESTIMATED MACTAQUAC INFLOW

ACRES



A - SMALL JAM 0.6 MILES ABOVE SIMONDS
B - ICE MOVING THROUGH SIMONDS
C - ICE MOVING THROUGH HARTLAND
D - JAM AT SPROULE'S ISLAND
E - JAM IN WEST CHANNEL AT INDIAN ISLAND RAILROAD BRIDGE
F - ICE MOVED DOWNSTREAM THROUGH THE EAST CHANNEL AROUND INDIAN ISLAND
G - RAILROAD BRIDGE FAILED
H - JAM AT WOODSTOCK PUMPING STATION
I - JAM AT BULLS CREEK
J - UPPER GUISIGUIT BROOK JAM RELEASED
K - ICE FROM UPPER GUISIGUIT BROOK JAM PASSING GAUGE LOCATION
L - JAM LOCATED AT SULLIVAN CREEK

Fig. 3.10

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
1987 SAINT JOHN RIVER FLOODING

WATER LEVELS
AT SIMONDS, HARTLAND, WOODSTOCK AND MACTAQUAC HEADPOND

ACRES

the Simonds gauge remained stationary. About 1 hour later the Hartland level had risen again. The interpretation of this phenomenon is that the Sproule's Island jam shoved (or consolidated) while a secondary jam (perhaps originally part of the Sproule's Island jam) held in place at Upper Becaguimec Island above Hartland. However, there was no specific observation of a jam at Upper Becaguimec Island. The water level in Simonds was at its maximum of about 161.5 ft from about 20:00, March 31 until about 02:00, April 1. At about 02:00 the Sproule's Island jam moved to Pine Island and the level in Simonds began to subside. The Simonds water level fluctuated between 153 and 155 ft for the rest of the day as jams worked their way down below Woodstock. Levels in Simonds reached a secondary peak of 160.3 ft at 14:00, April 2. This level corresponded to the maximum Beechwood release (310 000 ft^3/s) accompanied by the very large ice volume released from the Upper Guisiguit Brook ice jam. As this ice passed Simonds and the discharge reduced, the level in Simonds gradually dropped.

(ii) Hartland - Ice started to move through Hartland at 16:40, March 31. The level at the gauge immediately rose from about el 145.0 ft to 149.9 ft at 17:00. A jam was observed at Sproule's Island at 18:40 but the time history of levels suggests that this jam lodged before it was observed. The jam likely lodged between 17:00 and 18:00, March 31. At 21:35, ice started to move at the Hartland covered bridge and the gauge level dropped over 5 feet from 156.0 to 150.6 ft. By 23:00 the level had risen again--suggesting the abrupt fall and rise was the result of a shove (or consolidation) near the head of the Sproule's Island jam. The Hartland level reached its

maximum of 156.5 ft at 01:00, April 1. At 00:50, water was reported over the Pole Hill Road intersection (just upstream from Sproule's Island). No other impacts were reported in the Hartland area. At 01:20 the Woodstock gauge level rose rapidly and the Hartland gauge dropped 6 feet from el 156.5 ft to el 150.5 ft. At this time the Sproule's Island jam started its successive downstream movements to Pine Island and the Indian Island railroad bridge. The Indian Island railroad bridge jam caused a minor increase in Hartland water levels to 152.2 ft at about 11:00. When this jam dislodged, the levels in Hartland dropped again. A secondary peak level of 154.5 ft was reached at about 14:00, April 2, when ice from the Upper Guisiguit Brook jam together with peak Beechwood outflows passed down river. The Hartland levels then subsided to 151.2 ft. The level rose to 152.9 ft in response to the ice jam at Sullivan Creek. After 12:00 on April 3 the level at Hartland slowly dropped until it reached 145.0 ft at 24:00, April 5.

(iii) Indian Island Railroad Bridge - An ice jam was observed at the Indian Island railroad bridge (CPR Bridge, Mile 54.0, Shogomoc Subdivision) lodged in the main (west) channel around Indian Island. The secondary (east) channel around Indian Island was open (see Photograph 3.9). The jam lodgement in the west channel diverted a large proportion of the river flow through the open east channel. The abnormally large discharge in the east channel resulted in high velocities that undermined a pier and an abutment. Figure 3.10 shows that the Simonds and Hartland gauges experienced a relatively minor increase in water level due to this jam. This water level

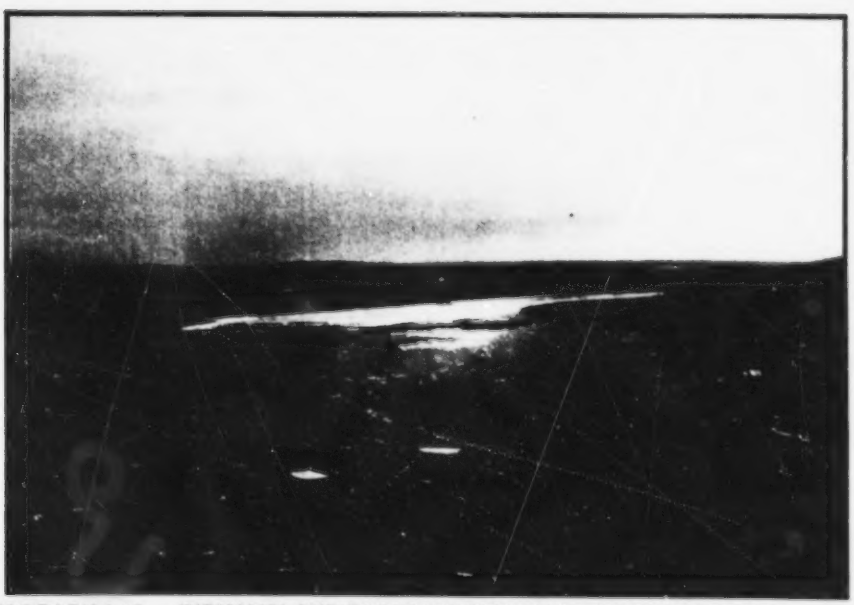
dropped when ice started to move through the secondary channel at 11:00, April 1. Two spans over the secondary channel failed at about 11:15. Photograph 3.10 shows the bridge just before this ice movement. The photograph shows a significant head loss (2 to 4 feet) through the bridge and a wake downstream from the piers. Just after the ice movement started, and prior to failure of the bridge, broken ice was beneath the bridge clearing the lower bridge chord by several feet (4 to 6 feet). At no time did moving ice contact the bridge superstructure. At this time (~11:10) ice was running through the secondary channel and an ice jam was still located in the main channel at the railroad bridge. The bridge failed when a pier and an abutment tumbled into the river. Shortly after ice moved through the east channel the water levels at Grafton, and then at Woodstock gauges, rose rapidly. Photograph 3.11 shows broken ice running through the secondary channel and thermal ice still located below the bridge over the main channel. At 14:45, April 1, there was open water in the secondary channel and downstream from the bridge over the main channel. However, broken ice was still being held in the main channel above the railroad bridge (see Photograph 3.12)

(iv) Woodstock - Throughout March 30, water levels in Woodstock were the same as the Mactaquac headpond level (130.0 to 131.5 ft). As the headpond was drawn down on subsequent days, the two levels diverged--the headpond dropping and Woodstock rising. The divergence was primarily a result of increasing river flow. Woodstock levels fluctuated at about 130.0 ft until about 12:00 on April 1 when the river flow

PHOTOGRAPH 3.9 **ICE JAM LODGEMENT AT INDIAN ISLAND RAILROAD BRIDGE**
LOCATION: INDIAN ISLAND
TIME/DATE: 10:48 - APRIL 1, 1987

PHOTOGRAPH 3.10 **HIGH VELOCITY FLOW UNDER INDIAN ISLAND RAILROAD BRIDGE**
LOCATION: INDIAN ISLAND EAST CHANNEL
TIME/DATE: ~11:00 - APRIL 1, 1987

PHOTOGRAPH 3.11 **INDIAN ISLAND RAILROAD BRIDGE AFTER FAILURE**
LOCATION: INDIAN ISLAND EAST CHANNEL
TIME/DATE: 12:01 - APRIL 1, 1987



PHOTOGRAPH 3.12 **INDIAN ISLAND RAILROAD BRIDGE AFTER FAILURE AND AFTER BROKEN ICE HAS FLUSHED THROUGH SECONDARY CHANNEL**
LOCATION: INDIAN ISLAND
TIME/DATE: 14:41 - APRIL 1, 1987

increased above 175 000 ft^3/s, and ice which had passed Indian Island railroad bridge lodged at the Woodstock pumping station. The Woodstock gauge rose to el 138.3 ft at 13:00--just before the pumping station jam moved downstream. The ice then formed successive jams near the "Cozy Cabins" at Lower Woodstock and just below Bulls Creek. The Bulls Creek jam held until 13:45, April 2. Just prior to release of this jam the Trans-Canada Highway near Bulls Creek was flooded. Approximately 3 hours later, at 16:35, broken ice was observed moving at about 1 ft/s near the final Sullivan Creek lodgement point. The ice was very fragmented and was crushing the thermal cover in front of it (see Photograph 2.4). At 08:00, April 3 the jam was observed in its final position at Sullivan Creek. Throughout the period from 13:00, April 1, to 24:00, April 2, the Woodstock level fluctuated between 136.6 ft and 140.0 ft. On April 3, the Woodstock level gradually rose to its maximum elevation of 143.9 ft. This maximum level was achieved 24 hours after the maximum estimated Mactaquac inflow. The maximum stage in Woodstock was therefore likely a result of the final Sullivan Creek jam configuration and storage of the peak inflow above the jam. During the period from about 13:00 to about 20:00 on April 3, the Mactaquac headpond level, Woodstock level and the Mactaquac <u>outflow</u> were approximately constant. Therefore, it is believed that an approximate steady state jam was achieved during this period with an inflow and outflow approximately equal to 260 000 ft^3/s. On April 4 and 5, the Woodstock level slowly dropped until it was 130.8 ft at 24:00, April 5.

4 - ASSESSMENT OF THE SEVERITY OF THE 1987 EVENTS

4 - ASSESSMENT OF THE SEVERITY OF THE 1987 EVENTS

At some important locations, the ice jam flooding on the Saint John River in 1987 was the most severe that has occurred since systematic water level measurements began. In this section of the report, the 1987 conditions are compared with those of other years in an effort to put the degree of severity into perspective. The extent of flooding, severity of ice conditions, severity of meteorologic conditions and severity of river flows are all examined.

Meteorologic conditions combined to produce a high rate of streamflow runoff at the end of March/beginning of April. A large amount of snow was on the ground and the rates at which it melted were among the two or three highest on record. A moderate amount of precipitation occurred during the 2 weeks preceding the ice jam period. The resulting streamflows were the highest ever recorded at the time of ice jamming.

The conditions which caused ice jam flooding on the Saint John River also caused flooding and severe damage in eight neighboring basins. In six of these cases the flooding resulted from ice jamming.

4.1 - Relative Severity of 1987 Events

The 1987 ice jam flooding in the Saint John River basin is among the worst flooding that has been recorded. Table 4.1 is the ranking of historic jam severity. The basis of the code assigned to each river reach is the spring freshette reports prepared each year by NBEPC. The assignment of the codes is somewhat subjective since damage estimates are not available for each year. The table shows that the years 1976 and 1987 both had severe damage. The subjective damage codes show that in 1976 there was extensive damage above Grand Falls while in 1987

TABLE 4.1

HISTORICAL SEVERITY OF ICE JAMS

Year	Above Grand Falls	Grand Falls to Beechwood	Beechwood to Mactaquac
1987	3	1	1
1986	4	4	2
1985	4	4	5
1984	4	4	5
1983	4	4	5
1982	4	4	4
1981	4	4	2
1980	4	5	4
1979	3	3	3
1978	4	4	4
1977	5	5	5
1976	1	1	1
1975	4	4	4
1974	2	5	5
1973	5	5	5
1972	5	5	4
1971	5	5	5
1970	2	5	2
1969	4	5	3
1968	3	3	2
1967	5	5	*
1966	5	4	
1965	5	5	
1964	3	3	
1963	4	5	
1962	5	5	
1961	5	5	
1960	4	5	
1959	5	3	
1958	5	5	

Severity classification is as follows.

1 - Serious flooding and extensive damage.
2 - Serious flooding and damage.
3 - Prolonged ice jams with probable local damage.
4 - Ice jams occurred - no known damage.
5 - Insignificant or no ice jams.

---

*Observation reports not prepared prior to 1968.

there was little damage. The table gives the same damage code to 1987 and 1976 for the Mactaquac and Beechwood reaches. However, the 1987 damages are known to be worse than those that occurred in 1976.

4.2 - Ice Conditions

The quantity (as measured by thickness) and the quality (strength) of the ice cover at the time when the ice breaks up can both affect the severity of ice jams. If the quantity of ice is large, the ice jams will be larger and potentially more destructive. If the ice is relatively unaffected by deterioration due to melting, the internal strength remains high. Ice jams of greater bulk strength can potentially back up river levels to greater heights.

Surveys of ice thickness are made several times each winter at various locations in each reservoir. Generally, safe access can only be assured in the reservoirs themselves and consequently ice data are not available for the natural river reaches. Surveys undertaken in 1987 show that the ice thickness was not unusual and was approximately normal. The major factor affecting the 1987 ice volume relates to movements of ice and not to the ice thickness. 1987 is the only year, since the construction of Beechwood, that ice moved down the entire length of the river--from above Fort Kent to below Woodstock. Previously, the ice for the Beechwood and Mactaquac reaches was contained within each reach. Ice from above Grand Falls frequently passes downstream into the Beechwood headpond. In many years the ice is delayed above Grand Falls until the ice above Beechwood is partially melted.

Observations of the 1987 ice jams suggest that the ice was of a relatively low strength. The ice near the head of several jams was crushed into small pieces and did not appear to contain large fragmented pieces of ice. These field observations of jams are supported by the pre-breakup ice surveys. In 1987, approximately 60% of the total ice

thickness was comprised of strong blue ice. This ratio is approximately normal. In contrast to 1987, the 1976 ice comprised over 95% blue ice. Photographs of 1976 conditions show large pieces of broken angular ice.

4.3 - Factors Affecting Jam Formation and Severity

The severity of ice jam events is generally affected either directly or indirectly by the meteorologic conditions immediately before and during the ice jams. Antecedent meteorologic conditions can lead to abnormally large breakup flows which in turn have a significant influence on ice jam severity. Meteorologic conditions when jams have formed are of less significance but can contribute to jam strength and, hence, movements. If strong winds occur they can have an influence on the balance of forces within ice jams.

Because of the influences of meteorology on river flows and ice jams, indexes have been used to compare the 1987 conditions to conditions for other years. The meteorologic indexes use Fredericton Airport data and are based upon previous analyses by Acres (1976) and Galbraith (1981). The meteorologic indexes that have been evaluated are

- length of breakup period
- accumulated thawing degree-days
- rate of heat transfer
- snowmelt index
- precipitation over the breakup period--both rate and total.

Table 4.2 is a summary of the indexes for a number of years. The values prior to 1981 were taken from Galbraith (1981) while the values for 1981 to 1987 were determined as part of this study. A ranking for river flow during ice breakup is included in Table 4.2 because these flows resulted from the meteorologic inputs. For comparative purposes,

TABLE 4.2

RANKED VALUES OF CALCULATED INDEXES

Year	Length of Breakup Period[1]		No. of Days to Reach ATDD = 50°C-days[2]		RHT (langleys/d)[3]		No. of to Rea SMI =
	Rank	Value	Rank	Value	Rank	Value	Rank
1987	5	13	3	13	2	159	2
1986	1	9	1	9	1	208	-
1985	19	30	25	36	11	93	-
1984	6	18	19	30	13	73	-
1983	8	21	27	38	14	67	-
1982	27	39	28	38	9	102	20
1981	2	11	32	40	4	119	-
1980	10	21	6	17	5	114	9
1979	20	30	11	23	15	64	4
1978	30	44	31	39	19	55	23
1977	22	32	7	21	20	50	12
1976	3	12	2	12	3	147	1
1975	25	34	26	36	25	37	-
1974	34	53	29	38	27	34	6
1973	11	22	10	23	26	34	-
1972	21	31	30	38	29	25	-
1971	17	29	18	29	18	60	14
1970	24	33	17	29	17	61	16
1969	23	33	22	34	23	43	17
1968	9	21	4	15	7	105	3
1967	29	44	15	28	12	86	13
1966	18	30	13	26	22	44	-
1965	32	50	33	42	-	-	21
1964	33	51	34	43	8	104	22
1963	16	28	9	22	21	46	8
1962	26	35	14	27	10	95	15
1961	15	28	20	30	28	25	-
1960	13	23	8	21	6	109	7
1959	31	50	24	36	24	42	19
1958	4	12	21	30	16	64	-
1957	28	42	23	35			18
1956	7	19	5	17			5
1955	12	23	12	23			10
1954	14	24	16	29			11

[1] From the first day, after February 28, that temperatures exc
[2] Number of days to accumulate 50°C-days of thawing (1954 - 1
[3] Average rate of heat transfer (langleys/d) over the breakup
[4] Number of days from beginning of breakup until the snowmelt
[5] Average daily precipitation over the breakup period (mm/d).
[6] Estimated breakup flow at Woodstock. For the period 1954 -
For the period 1968 - 1987 calculated Mactaquac inflows on
[7] Severity classification is subjective and uses the following
1 - serious flooding - extensive damage
2 - serious flooding - damage
3 - prolonged ice jams with probable local damage
4 - ice jams occurred - no known damage
5 - insignificant or no ice jams.
[8] 'na' indicates the index did not reach 90 mm during breakup.

No. of Days to Reach SMI - 90 mm[4]		Rate of Precipitation[5] mm/d)		Total Precipitation Over the Breakup Period (mm)		River Flow During Breakup[6] (ft^3/s)		Ice Jam Severity[7] Classification	
Rank	Value	Rank	Value	Rank	Value	Rank	Value	Grand Falls to Beechwood	Beechwood to Mactaquac
2	13	18	1.8	22	23	1	250 700	1	1
-	na[8]	1	4.8	20	43	5	134 500	4	2
-	na	16	2.0	14	60	32	21 100	4	5
-	na	3	4.2	11	76	16	76 100	4	5
-	na	2	4.2	8	88	29	41 900	4	5
20	37	13	2.5	5	98	6	129 900	4	4
-	na	23	0.9	23	10	28	44 200	4	2
9	22	12	2.5	17	53	13	84 500	5	4
4	15	6	3.6	4	108	4	162 600	3	3
23	45	17	1.9	9	84	8	105 300	4	4
12	25	14	2.2	12	70	14	80 500	5	5
1	9	5	3.9	19	47	2	206 500	1	1
-	na	11	2.7	6	92	20	61 600	4	4
6	17	7	3.4	1	180	17	71 200	5	5
-	na	10	2.7	15	59	22	55 700	5	5
-	na	4	4.0	3	124	19	66 500	5	4
14	27	15	2.1	13	61	12	88 100	5	5
16	31	9	2.7	7	89	-	-	5	2
17	32	21	1.7	16	56	30	40 700	5	3
3	14	22	1.5	21	32	11	88 400	3	2
13	26	19	1.8	10	79	-	-	5	
-	na	20	1.7	18	51	25	47 300	4	
21	41	-	-	-	-	26	45 900	5	
22	43	8	2.7	2	138	10	89 900	3	
8	21					9	104 000	5	
15	27					27	45 600	5	
-	na					18	67 800	5	
7	17					7	110 000	5	
19	34					15	78 500	3	
-	na					31	35 400	5	
18	32					23	53 200		
5	16					21	56 300		
10	23					3	173 000		
11	23					24	47 400		

res exceed 0°C until the last day of ice at East Florenceville (1954 - 1987).
954 - 1987).
reakup period (1957 - 1987).
owmelt index reaches 90 mm (1954 - 1987).
mm/d).
1954 - 1967 Pokiok flows on the day after last reported ice at the gauge are listed.
lows on the day of Woodstock breakup are listed.
llowing scale.

reakup.

rankings of jam severity for the Grand Falls to Beechwood and Beechwood to Mactaquac reaches are also included in this table. The meteorologic indexes and river flow are discussed below.

(a) Length of Breakup Period

A short rapid breakup is usually associated with ice jam conditions, while a long slow breakup can often result in the cover rotting in place and causing no problems. Table 4.2 ranks 1987 fifth (out of 34 years) and 1976 third. The year 1986 ranked first. New Brunswick, in general, experienced a lot of ice jam related flooding in 1986. On the Saint John River (in 1986) Simonds and Hartland had the highest stages of record. Woodstock levels approached the 1976 values. Table 4.2 shows that the rankings of jam severity and length of breakup period are not closely related for the Saint John River.

(b) Accumulated Thawing Degree-Days (ATDD)

Thawing degree-days are often used as an indicator of heat gain to the ice and snow in the basin. The rate of heat gain dictates the rate of snowmelt and ice thawing and therefore influences the peak discharge in the river and the propensity for ice jamming. Galbraith (1981) selected an index that is the number of days for ATDD to reach 50°C-days. Table 4.2 shows that the number of days for ATDD to reach 50°C-days frequently coincides with the length of the breakup period. Table 4.2 also shows that ATDD can provide a guide to top ranking events.

(c) Rate of Heat Transfer (RHT)

Heat transfer to the basin was evaluated using estimates of the following components of the energy balance

(i) Incident Solar Radiation - estimated from hours of sunshine

(ii) Reflected Solar Radiation - estimated assuming that 50% of the incident solar radiation is reflected

(iii) Incident Atmospheric Radiation - estimated from air temperature, cloud amount, and vapor pressure

(iv) Reflected Atmospheric Radiation - estimated assuming that 3% of the incident atmosphere radiation is reflected

(v) Long Wave Radiation Emissions from the Surface - estimated from the snow surface temperature assuming an emissivity factor of 0.97

(vi) Conductive Heat Transfer - estimated from air temperature, snow surface temperature and the wind speed.

The method of estimating these components was based on Galbraith (1981).

The RHT index is the average daily heat transfer over the breakup period. Table 4.2 shows that RHT is high for 1986, 1987 and 1976.

(d) Snowmelt Index (SMI)

The snowmelt index is semi-empirical and accounts for convection/conduction and condensation of water vapor onto the snowpack. The formula used is taken from Galbraith (1981) and includes wind speed, temperature and water vapor pressure data. The constants are chosen so that SMI is approximately equivalent to millimeters of melt. During the period from March 18 to March 31, 1987, the SMI was 67 mm. The observed snowmelt was between 50 and 75 mm, thus approximately confirming the choice of the constants.

Table 4.2 shows that the SMI ranking corresponds well with the ice jam severity ranking.

(e) Precipitation

Galbraith (1981) found that the rate of precipitation over the breakup period was the least significant of the 5 indexes examined. As can be seen from the results in Table 4.2, our findings concur.

Similarly, total precipitation during the breakup period is also not a good index.

(f) River Flow During Ice Breakup

River flow is an important determinant of ice jam severity. The river flow is important for three reasons

- larger river flows result in larger forces on ice jams and hence the jams remaining in place are thicker

- larger river flows can result in dislodgement of an ice jam and a reduction in upstream water levels (see Section 2.3.2)

- larger river flows result in higher water levels (if the jam stays lodged).

The river flow that is significant is the maximum flow during the time of lodgement in the jam location. Generally the flow associated with a particular jam is not known with any great degree of certainty. There are several difficulties determining the 'correct' flow.

- Streamflow gauging stations are not located exactly at jam locations.

- Ice effects on stage discharge rating curves influence the accuracy of any flow estimates.

- Ice jams form and release creating dynamic flow conditions. When a jam forms, the flow at the tail of the jam could be considerably larger than the flow through the jam. When the jam eventually releases, downstream locations could experience a large localized flow that attenuates over time and distance.

Because jam severity is dependent upon the flow at the jam it has become normal practice to use river flow at the time of ice breakup as a guide to the severity of related ice jam problems. The river flow that has been selected is the Mactaquac inflow on the last day of observed ice at Woodstock.

Table 4.2 shows that the ranking of river flow at the time of ice breakup corresponds well with the ice jam severity ranking.

The 1987 ice jams resulted from a combination of meteorologic and hydrologic factors which are somewhat unusual. The compounding of several unusual factors (although not exceptionally rare) resulted in exceptionally severe ice jams. The analyses of factors affecting ice jam formation and severity does not permit prediction of the rank of ice jam severity. However, the heat input index, snowmelt index and river flow during ice breakup do provide a guide (not a predictor) to the severity of ice jams.

4.4 - Floods in Adjacent River Basins

Flooding during the first few days of April, 1987, was not confined to the Saint John River valley. Other rivers in New Brunswick, Maine and Quebec also experienced flooding and associated damages. Table 4.3 shows a summary of floods that were reported in these areas. The locations of the reported floods are shown in Figure 4.1.

Eight rivers, in addition to the Saint John River, had flooding. Of these eight, six had ice jam related floods and two had open water floods. The cause of the high discharge for both types of flooding was

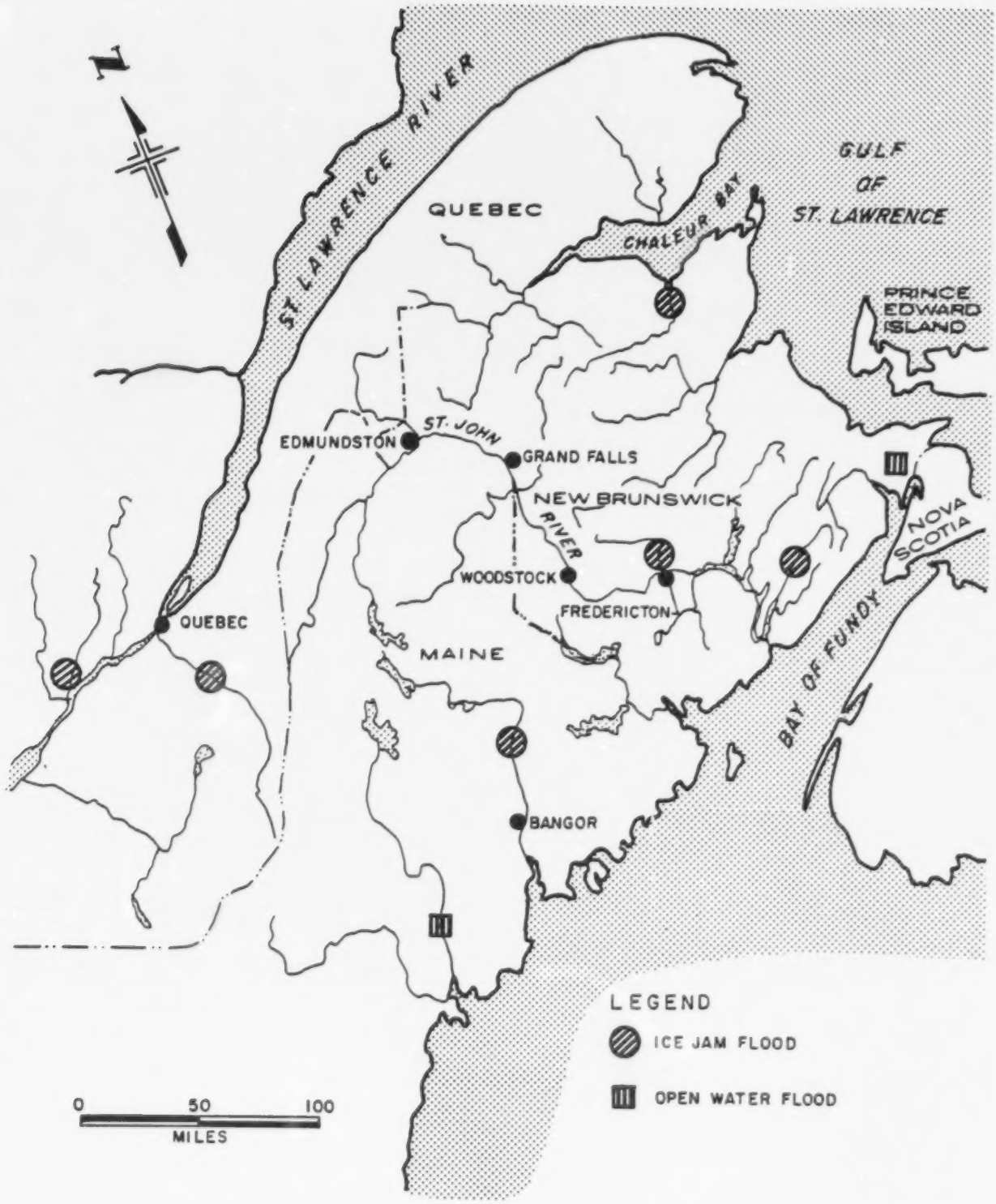


FIG. 4.1

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
1987 SAINT JOHN RIVER FLOODING

LOCATIONS OF FLOODS IN ADJACENT BASINS

ACRES

a combination of rainfall and warm temperatures which resulted in rapid snowmelt. The damages were generally less extensive than those that occurred along the Saint John River. However, one other railroad bridge failed. The CPR bridge over the St. Anne River at Ste-Anne-de-la-Perade, Quebec, lost three of six spans due to ice impact. This bridge is on the main CPR line between Montreal and Quebec city.

TABLE 4.3

FLOODING IN ADJACENT BASINS

General Location	River Name	Type of Flooding	Dates of 'Problems'	Description of Flooding	Sources
Fredericton, N. B.	Nashwaak	ice jam	April 2, 3	jams at Stanley, Nashwaak bridge, Pleasant valley, Taymouth; Stanley flooded--extensive damage to property	Mr. B. Burrell[1] newspapers
Sussex, N.B.	Kennebecasis	ice jam	April 1	jam at Norton; localized flooding and little or no damage	Mr. B. Burrell[1] newspapers
Bathurst, N.B.	Middle	ice jam	April 2	seven homes and cottages flooded	newspapers
Southeast, N.B.	Memramcook	open water	April 2	two highways closed; no evacuation (very few homes located beside river)	Mr. A. D. Kindervater[2] newspapers
Augusta, Maine	Kennebec	open water	April 2, 3	"State of Emergency" declared; extensive damage	Mr. D. Cowing[3] newspapers
Northern Maine	Penobscot	ice jam	April 2	no major evacuations or injuries reported	Mr. D. Cowing[3] newspapers
Sainte-Marie-de-Beauce, Quebec	Chaudiere	ice jam	April 1, 2	450 families evacuated, highways cut, river 8 m above normal stage	newspapers
Ste-Anne-de-la-Perade, Quebec	St. Anne	ice jam	April 1	CPR bridge (built 1909) between Trois-Rivieres and Quebec city damaged by ice (3 of 6 spans collapsed)	newspapers

[1]Mr. B. Burrell - New Brunswick Department of Municipal Affairs and Environment, Fredericton.

[2]Mr. A. D. Kindervater - Water Planning and Management Branch, Inland Waters Directorate, Environment Canada, Dartmouth.

[3]Mr. D. Cowing - Chief - United States Geological Survey, Augusta, Maine.

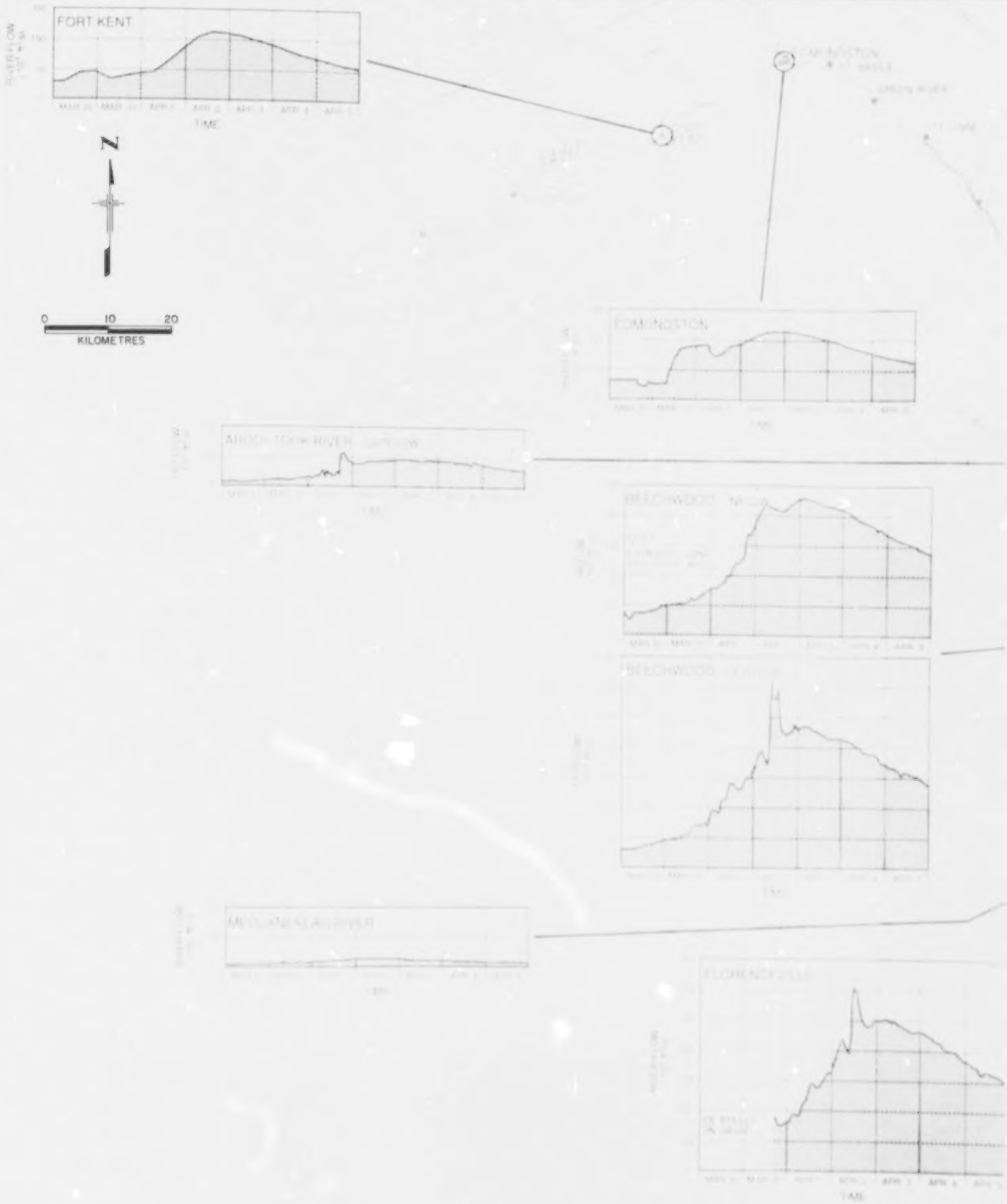
REFERENCES

REFERENCES

Acres, "Saint John River Analysis of 1976 Ice Jams", September 1976.

Galbraith, P. W., "On Estimating the Likelihood of Ice Jams on the Saint John River Using Meteorological Parameters", 5th Canadian Hydrotechnical Conference, Fredericton, New Brunswick, May 1981.

PLATES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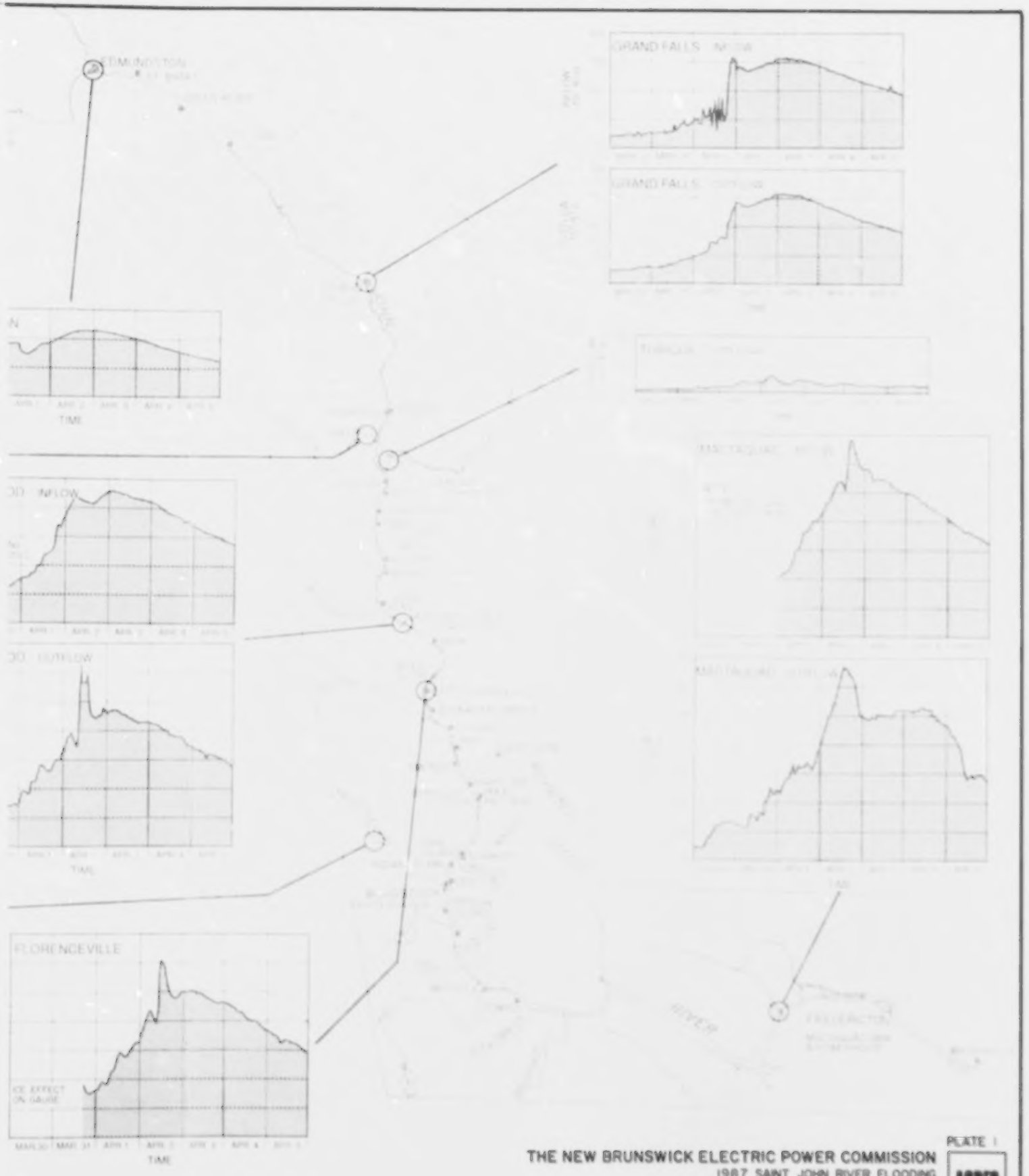


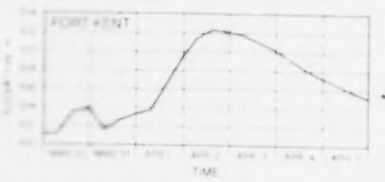
PLATE 1

THE NEW BRUNSWICK ELECTRIC POWER COMMISSION

1987 SAINT JOHN RIVER FLOODING

FLOW CHRONOLOGY

ACRES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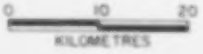
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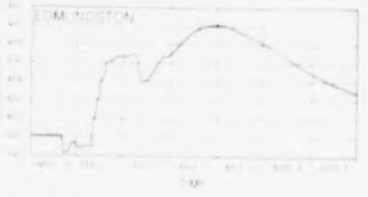
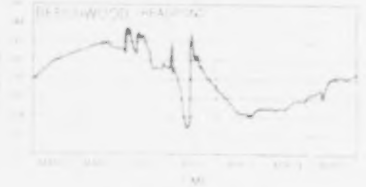
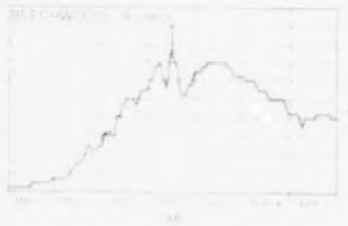
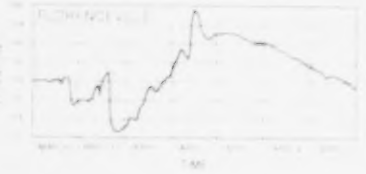
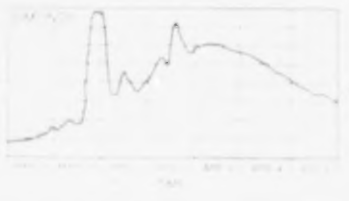
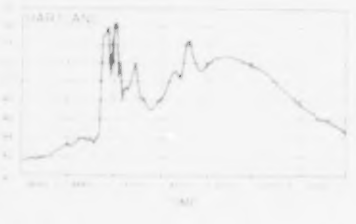

SUMMERSTON
TIME

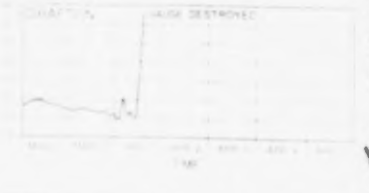


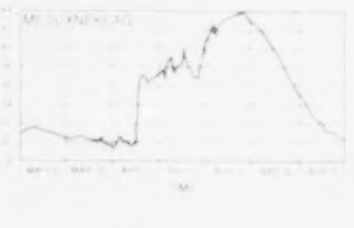


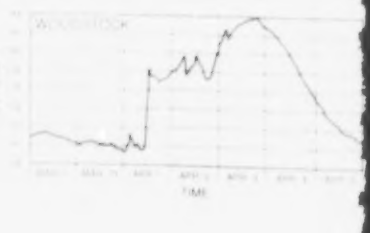


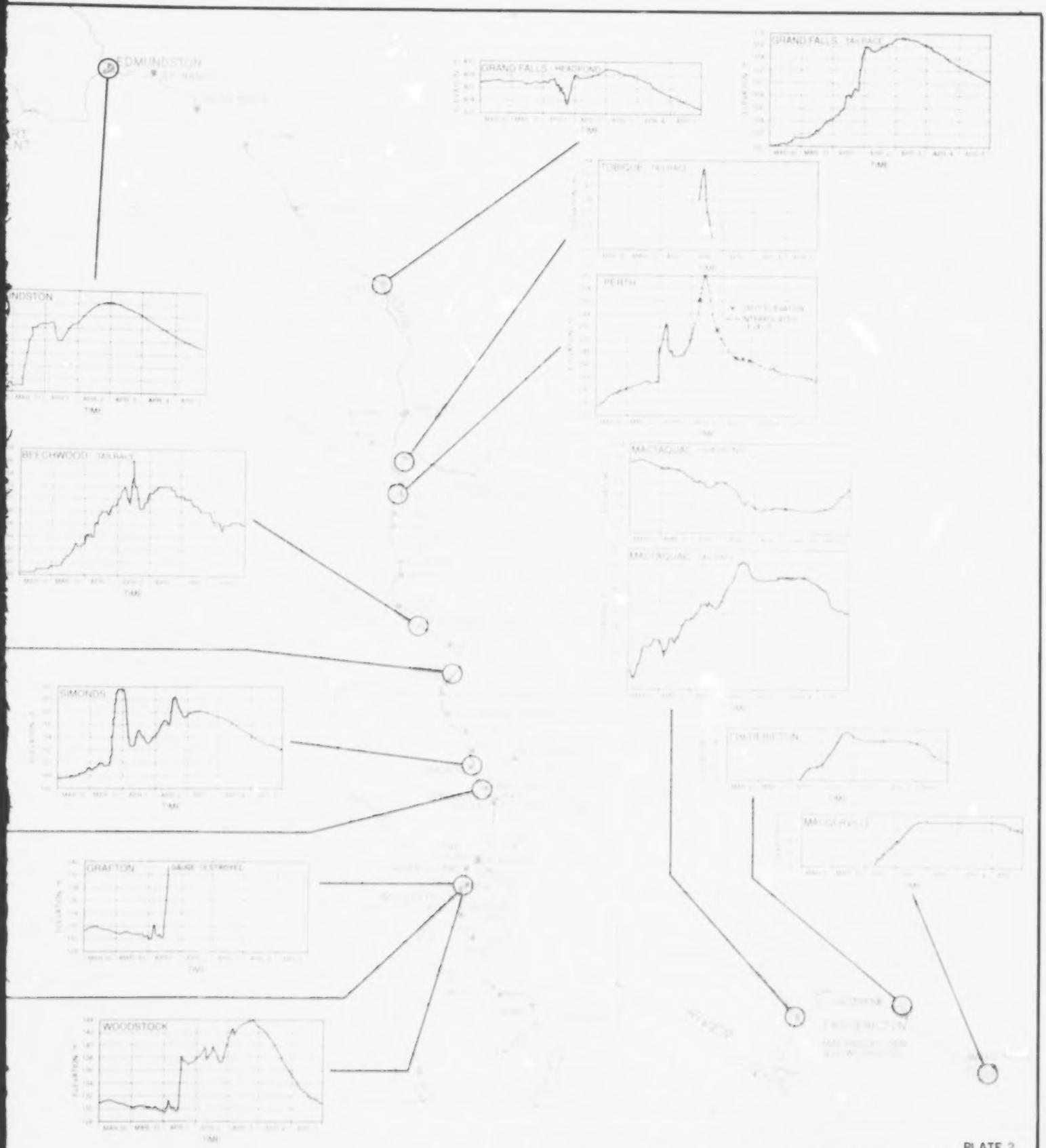












THE NEW BRUNSWICK ELECTRIC POWER COMMISSION

1987 SAINT JOHN RIVER FLOODING

WATER LEVEL CHRONOLOGY

PLATE 2

AGRA

Tinker

Date	Time	Comment
Mar 27 87 to Mar 29 87		Aroostook River open 3.6 m down from Tinker
Mar 29 87	18:00	Tinker started spilling
Mar 31 87	13:30	Aroostook River open from Caribou to Ft. Fairfield
Apr 1 87	05:30	Ice let go at Caribou on Aroostook River. Predicted to arrive at Tinker in 5 hours
	17:30	Tinker started spilling ice

Grand Falls

Date	Time	Comment
Mar 27 87 to Mar 29 87		Open from Grand Falls down 2.5 m
Mar 30 87	15:30	Open from Grand Falls down 4.5 m, then 0.6 m broken ice
Mar 31 87	09:00	Open from Grand Falls down 12 m, then 4 m broken ice, then solid to Beechwood
	11:30	Open from Grand Falls down 11 m, then 4 m broken ice, then 3 m open, then 4 m broken ice
	13:00	Open from Grand Falls down 12 m, then 2 m broken ice, then 0.3 m open, then 4 m broken ice
	17:15	Open from Grand Falls down 16 m
Apr 1 87	08:00	Open from Grand Falls to 4 m below Perth bridge
	09:00	*Grand Falls headpond drawdown started*
	18:00	*Maximum drawdown at Grand Falls headpond achieved prior to ice flushing*
	20:00	Grand Falls started to spill ice. All sluice gates wide open
Apr 2 87	11:00	Grand Falls stopped spilling ice

Morrell/Baker's Ferry

Date	Time	Comment
Mar 31 87	16:00	Small jam in Morrell area
	17:15	Holding 8 ft of water and over road
	20:15	Open 2 m above Baker's Ferry. Jammed ~4.5 m below Morrell Siding. Road flooded at Baker's Ferry

Beechwood Dam and Powerhouse

Date	Time	Comment
Mar 30 87	08:30	Beechwood started spilling water
Apr 2 87	00:30	Heavy drawdown started at Beechwood. 8 of 9 gates raised from 5.5 to 12.5 opening
	02:00	Gates raised to 14 ft. Grand Falls ice and water arriving and building above jam
	06:00	Three gates cleared of water surface
	07:00	Four gates cleared of water surface
	07:45	Photos show open water and wall rolled thermal cover just above Beechwood
	08:00	Five gates cleared of water surface
	08:45	*Beechwood headpond dyed rose - jam released water*
	09:30	Some Beechwood ice started through 5 open gates
	09:34	Ice moving above Beechwood
	09:35	Headpond rising rapidly
	09:55	Beechwood started spilling ice. Packed ice 0.5 m above Beechwood
	12:00	Six gates cleared of water surface
	11:00	All Beechwood ice now moving
	11:35	2 m of broken ice above Beechwood
	14:00	All ice reported passed through Beechwood. Units started up (over [illegible] thermals clogged with ice

Simonds/Hartland Area

Date	Time	Comment
Mar 30 87	15:00	Ice has run at Beaugumec Stream. Open from Beaugumec Stream to Spruce's Island, then ice covered to Mactaquac
	22:00	Small run of ice from Stickney to Simonds
Mar 31 87	06:00	Open river for 3 m through Stickney and Simonds. *Small 0.6 m cong jam above Simonds gauge at Pear Island*
	08:53	3 m of broken stationary ice above Hartland then 3 m open
	15:45	Ice moving in Simonds area
	16:40	Ice moving through Hartland area
	18:40	Jam at Spruce's Island. Water reached road in Simonds. Ice below Hartland covered bridge
	19:20	Water over road in Simonds
	20:15	Road closed in Simonds
	21:35	Ice started moving at Hartland covered bridge
Apr 1 87	00:50	Water on Pole Hill Road intersection
	01:20	Jam at Spruce's Island let go
	03:00	Jam below Simonds at Upper Beaugumec Island let go and moved through Hartland
Apr 2 87	13:00	Beechwood ice flowing by Deep Creek below Hartland

Woodstock

Date	Time	Comment
Mar 30 87	15:00	Meduxnekeag River ice has run into interval
Apr 1 87	23:45	Sheet ice below Woodstock
	12:00	Ice at Grafton and jamming badly. Head at Woodstock jumping [illegible] ice just above Indian Island railroad bridge
	13:30	Meduxnekeag River ice still held in interval. Ice moving in Woodstock. Head at Cozy Cabins. Jam at Woodstock
	15:30	Ice moved to 0.5 m below Cozy Cabins at Lower Woodstock
	16:30	Ice packing on Grafton side of river
	16:45	Photos show an open lead on the Grafton side
	18:00	Photos show moving ice in Woodstock (~20% coverage)
Apr 2 87	07:00	Ice moving at Woodstock
	06:50	Jam 0.5 m below Butts Creek
	13:35	Beechwood to Woodstock is all ice released from Beechwood
Apr 3 87	19:00	Woodstock level peaked at 143.8 ft.
Apr 3 87	20:30	Woodstock levels started to drop
	21:00	Ice started to run from the interval. (Approximately 1-6 moved out)
Apr 4 87	07:00	Meduxnekeag ice clear of railroad bridge

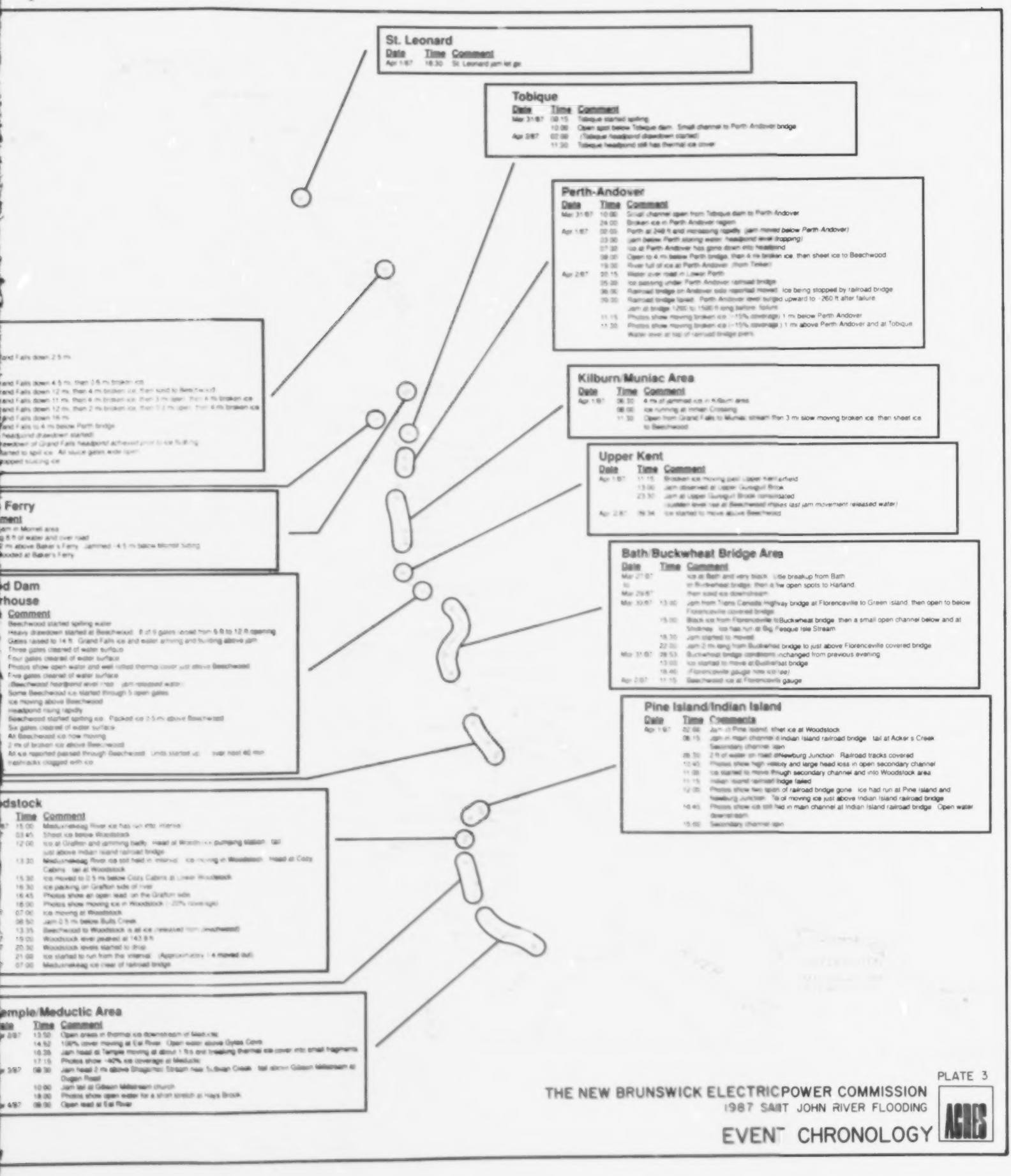
Riordan Island/Gibson Millstream Area

Date	Time	Comment
Apr 1 87	10:00	Photos show open lead at Gibson Millstream
Apr 2 87	07:30	Broken ice in Butts Creek area
	08:50	Jam 0.5 m below Butts Creek and holding
	09:55	Butts Creek jam on east side of river. Open on west side and causing erosion along Trans Canada Highway
	10:45	Photos show a large stretch of open water near Gibson Millstream, thermal cover downstream and open water at Butts Creek interchange/intersection causing erosion near the road
	11:40	Channel full of broken ice above Butts Creek, then open to Riordan island, then 1 m of sheet ice
	12:00	Ice moved at Butts Creek
	12:05	Trans Canada highway at Butts Creek closed. Took guard rails by erosion, not ice
	13:45	Butts Creek jam let go
	13:50	Photos show previous open area at Gibson Millstream now full of broken ice
	14:52	Ice moving (~50% coverage) at Gibson Millstream. 100% cover upstream of Indian Village
Apr 3 87	00:25	Water over Trans Canada highway at Butts Creek
	02:00	Trans Canada highway closed at Butts Creek
	03:40	1.5 ft of water on Trans Canada highway at Butts Creek
	10:00	Jam up at Gibson Millstream church. Ice running (~20% coverage)
	12:00	Photos show ice accumulated at toe of dam - loose ice on surface
	18:00	Photos show toe well above Gibson Millstream
	21:00	Butts Creek level down 13 m
Apr 4 87	08:00	Photos show toe receding and now below Gibson Millstream

Temple/Meductic Area

Date	Time	Comment
Apr 2 87	13:50	Open areas in thermal ice downstream of Meductic
	14:52	100% cover moving at Eel River. Open water above Dyke Cove
	16:35	Jam head at Temple moving at about 1 fps and breaking thermal ice cover into sheet ice
	17:15	Photos show ~40% ice coverage at Meductic
Apr 3 87	08:30	Jam head 2 m above Shogomoc Stream near Bulmer Creek. Toe above Gibson Dugan Road
	10:00	Jam toe at Gibson Millstream church
	18:00	Photos show open water for a short stretch at Hays Brook
Apr 4 87	08:00	Open lead at Eel River

NOTE
ITALIC COMMENTS ARE INFERENCES FROM DATA
ALL OTHER COMMENTS ARE ACTUAL OBSERVATIONS


St. Leonard
Date Time Comment
Apr 1/87 16:30 St. Leonard jam let go
Tobique
Date Time Comment
Mar 31/87 08:15 Tobique started spring
10:00 Open spot below Tobique dam. Small channel to Perth Andover bridge
Apr 2/87 02:00 (Tobique headpond drawdown started)
11:30 Tobique headpond still has thermal ice cover
Perth-Andover
Date Time Comment
Mar 31/87 10:00 Small channel open from Tobique dam to Perth Andover
24:00 Broken ice in Perth Andover region
Apr 1/87 02:00 Perth at 248 ft and increasing rapidly (jam moved below Perth Andover)
03:00 jam below Perth storing water, headpond level dropping)
07:30 ice at Perth Andover has gone down into headpond
08:00 Open to 4 mi below Perth bridge, then 4 mi broken ice, then sheet ice to Beechwood
19:30 River full of ice at Perth Andover (from Tinker)
Apr 2/87 00:15 Water over road in Lower Perth
05:00 Ice passing under Perth Andover railroad bridge
06:00 Railroad bridge on Andover side reported moved, ice being stopped by railroad bridge
10:00 Railroad bridge tipped. Perth Andover deck surged upward to ~260 ft after failure
Jam at bridge 1250 to 1500 ft long before failure
11:15 Photos show moving broken ice (~15% coverage) 1 mi below Perth Andover
11:30 Photos show moving broken ice (~15% coverage) 1 mi above Perth Andover and at Tobique
Water over at top of railroad bridge piers
Kilburn/Muniac Area
Date Time Comment
Apr 1/87 06:30 4 mi of jammed ice in Kilburn area
08:00 Ice running at Inhabitants Crossing
11:30 Open from Grand Falls to Muniac stream then 3 mi slow moving broken ice, then sheet ice to Beechwood
Upper Kent
Date Time Comment
Apr 1/87 11:15 Broken ice moving past Upper Kent airfield
13:00 Jam observed at Upper Quisibis Brook
23:30 Jam at Upper Quisibis Brook consolidated
(sudden level rise at Beechwood implies last jam movement released water)
Apr 2/87 16:34 Ice started to move above Beechwood
Bath/Buckwheat Bridge Area
Date Time Comment
Mar 27/87 ice at Bath and very black. Little breakup from Bath
to in Buckwheat bridge, then a few open spots to Harland
Mar 29/87 then sheet ice downstream
Mar 30/87 13:00 Jam from Trans Canada Highway bridge at Florenceville to Green Island, then open to below Florenceville covered bridge
15:30 Black ice from Florenceville to Buckwheat bridge, then a small open channel below and at Shiloney. Ice has run at Big Pesaque Isle Stream
18:30 Jam started to reveal
22:30 Jam 2 mi long from Buckwheat bridge to just above Florenceville covered bridge
Mar 31/87 09:53 Buckwheat bridge conditions unchanged from previous evening
13:00 Ice started to move at Buckwheat bridge
19:40 (Florenceville gauge now ice free)
Apr 2/87 11:15 Beechwood ice at Florenceville gauge
Pine Island/Indian Island
Date Time Comments
Apr 1/87 02:00 Jam at Pine Island, sheet ice at Woodstock
08:15 Jam in main channel at Indian Island railroad bridge, tail at Acker's Creek
Secondary channel open
09:30 2 ft of water on road at Newburg Junction. Railroad tracks covered
10:40 Photos show high velocity and large head loss in open secondary channel
11:00 Ice started to move through secondary channel and into Woodstock area
11:15 Indian Island railroad bridge failed
12:00 Photos show two spans of railroad bridge gone, ice had run at Pine Island and Newburg Junction. Tail of moving ice just above Indian Island railroad bridge
16:40 Photos show ice still held in main channel at Indian Island railroad bridge. Open water downstream
15:00 Secondary channel open
Ferry
ment
jam in Morrell area
g 8 ft of water and over road
2 mi above Baker's Ferry. Jammed ~4.5 mi below Morrell Siding
oaded at Baker's Ferry
d Dam
rhouse
Comment
Beechwood started spring water
Heavy drawdown started at Beechwood. 8 of 9 gates raised from 9.9 to 12.9 opening
Gates raised to 14 ft. Grand Falls ice and water arriving and building above jam
Three gates cleared of water surface
Four gates cleared of water surface
Photos show open water and well rafted thermal cover just above Beechwood
Five gates cleared of water surface
(Beechwood headpond level rises - jam released water)
Some Beechwood ice started through 5 open gates
Ice moving above Beechwood
Headpond rising rapidly
Beechwood started spring ice. Packed ice 2.5 mi above Beechwood
Six gates cleared of water surface
All Beechwood ice now moving
2 mi of broken ice above Beechwood
All ice reported passed through Beechwood. Units started at ... now next 40 min
Washouts clogged with ice
dstock
Time Comment
15:00 Meduniekeag River ice has run into Intervale
03:45 Sheet ice below Woodstock
12:00 Ice at Grafton and jamming badly, Head at Woodstock pumping station, tail just above Indian Island railroad bridge
13:30 Meduniekeag River ice still held in Intervale, ice moving in Woodstock. Head at Cozy Cabins, tail at Woodstock
15:30 Ice moved to 0.5 mi below Cozy Cabins at Lower Woodstock
16:30 Ice packing on Grafton side of river
16:45 Photos show an open lead on the Grafton side
18:00 Photos show moving ice in Woodstock (~20% coverage)
07:00 Ice moving at Woodstock
08:50 Jam 0.5 mi below Bulls Creek
13:35 Beechwood to Woodstock is all ice (released from Unechwood)
19:00 Woodstock level peaked at 143.8 ft
20:30 Woodstock levels started to drop
21:00 Ice started to run from the Intervale. (Approximately 1/4 moved out)
07:00 Meduniekeag ice clear of railroad bridge
emple/Meductic Area
ate Time Comment
r 2/87 13:50 Open areas in thermal ice downstream of Meductic
14:52 100% cover moving at Eel River. Open water above Gyles Cove
16:35 Jam head at Temple moving at about 1 ft/s and breaking thermal ice cover into small fragments
17:15 Photos show ~40% ice coverage at Meductic
r 3/87 08:30 Jam head 2 mi above Shaganish Stream near Sullivan Creek, tail above Gibson Millstream at Dugan Road
10:00 Jam tail at Gibson Millstream church
18:00 Photos show open water for a short stretch at Hays Brook
r 4/87 08:30 Open lead at Eel River
PLATE 3
THE NEW BRUNSWICK ELECTRIC POWER COMMISSION
1987 SAINT JOHN RIVER FLOODING
EVENT CHRONOLOGY
ACRES

APPENDIX A

DETAILED CHRONOLOGY TABLES

DATE	TIME	FORT KENT NBEPC ELEVATION (Measured in ft)	FORT KENT NBEPC DISCHARGE (Calc.1 in ft³/s)	EDMUNDSTON WSC-01AD004 ELEVATION (Measured in ft)	EDMUNDSTON WSC-01AD004 DISCHARGE (Calc.1 in ft³/s*)	GRAND FALLS NBEPC/WSC-01AF002 HEADPOND EL. (Measured in ft)	GRAND FALLS NBEPC/WSC-01AF002 INFLOW (Calc.2 in ft³/s)	GRAND FALLS NBEPC/WSC-01AF002 ELEVATION** (Measured in ft)	GRAND FALLS NBEPC/WSC-01AF002 OUTFLOW (Calc.1 in ft³/s)	TOBIQUE RIVER NBEPC HEADPOND EL. (Measured in ft)	TOBIQUE RIVER NBEPC TAILRACE EL. (Measured in ft)	TOBIQUE RIVER NBEPC INFLOW (Calc.2 in ft³/s)	TOBIQUE RIVER NBEPC OUTFLOW (Calc.3 in ft³/s)	ARROOSTOOK RIVER WSC 01AG003 OUTFLOW (Calc.1 in ft³/s*)	PERTH-NBEPC ELEVATION (Measured in ft)	BEECHWOOD NBEPC HEADPOND EL. (Measured in ft)	BEECHWOOD NBEPC TAILRACE EL. (Measured in ft)	BEECHWOOD NBEPC INFLOW (Calc.4 in ft³/s)	BEECHWOOD NBEPC OUTFLOW (Calc.3 in ft³/s)	BEECHWOOD NBEPC JAM POSITION	OBSERVED JAM LOCATION HEAD	OBSERVED JAM LOCATION TAIL	OBSERVED JAM LOCATION TIME	GRAN
27-Mar-87 to 29-Mar-87	1800																							< Open from Grand F
30-Mar-87	100	501.08	31288	448.12	31656	426.80	23265	300.03	23000	306.20	3800	3800	7628	239.40	238.20	188.50	35215	29500						open 1 km down fr
	200					426.85	23265	300.03	23000	306.25	3800	3800	7805	239.60	238.30	188.50	27069	29500						< Tinker started sp
	300					426.90	23265	300.03	23000	306.25	3800	3800	7875	239.80	238.50	188.50	25770	29500						
	400					426.95	23265	300.03	23000	306.30	4400	3800	9217	240.00	238.70	188.50	29745	29500						
	500					427.00	23265	300.03	23000	306.30	3800	3800	8935	240.20	238.90	188.50	35738	29700						
	600					427.00	23685	300.13	24000	306.35	4400	3800	8687	240.40	239.15	188.50	38433	29701						
	700	501.29	32345	448.12	31656	427.00	24805	300.39	25000	306.35	3880	3880	8440	240.60	239.40	188.50	38053	29800						
	800					427.00	24805	300.39	25000	306.40	4480	3880	7593	240.80	239.55	188.50	37848	29800						
	830																							< Beechwood started
	900					427.00	24805	300.39	25000	306.45	4480	3880	7063	241.00	239.75	188.50	37398	32100						
	1000					427.15	28550	300.39	25000	306.50	4580	3980	7346	241.20	239.95	188.50	37457	31515						
	1100					427.15	26070	300.26	24000	306.50	3980	3980	6816	241.30	240.00	188.50	38538	34040						
	1200					427.15	23965	300.19	24000	306.50	3980	3980	7134	241.30	240.10	189.00	38663	34970						
	1300					427.05	21920	300.59	26000	306.55	4580	3980	7593	241.60	240.20	189.00	38984	34980						
	1400					427.15	29360	300.59	26000	306.60	4580	3980	8193	241.50	240.30	189.00	39452	36650						
	1500	503.58	45054	448.12	31656	427.25	29470	300.59	26000	306.65	4580	3980	8793	241.40	240.40	189.00	39891	36660						< Open from Grand F
	1600					427.25	26620	300.82	27000	306.75	5180	3980	8829	241.70	240.40	189.00	41247	37430						broken ice.
	1630																							
	1700			446.18	21857	427.00	19940	301.44	29000	306.85	5180	3980	8299	241.70	240.50	189.00	42684	37430						
	1800			446.29	22182	426.95	26895	301.28	29000	307.05	6380	3980	8476	241.90	240.70	189.00	43064	39600						
	1900			445.90	20322	426.90	26920	301.28	29000	307.20	5780	3980	10100	241.90	240.70	189.00	44069	41160						
	2000			445.75	19577	426.90	28575	301.28	29000	307.35	5680	3880	10842	241.90	240.80	189.00	47090	41160						
	2100			447.46	26042	426.95	30230	301.28	29000	307.55	6280	3880	10912	242.10	240.85	189.00	49281	43080						
	2140																							
	2200			447.45	27983	426.95	28715	301.31	29000	307.75	6280	3880	11054	242.30	241.00	189.50	49982	43105						
	2300	503.81	48444	446.95	25461	426.95	28715	301.31	29000	307.90	5680	3880	11265	242.30	241.15	189.50	50386	44845						
	2400			446.85	24943	426.95	28715	301.31	29000	308.10	6280	3880	11513	242.30	241.15	189.50	50777	44995						
31-Mar-87	100			446.84	24884	426.95	28715	301.31	29000	308.40	7480	3880	11760	242.40	241.15	189.50	51095	44995						
	200			446.89	25135	426.95	28715	301.31	29000	308.60	6280	3880	11901	242.60	241.15	189.50	51341	44995						
	300			446.98	25608	426.95	28715	301.31	29000	308.90	7480	3880	11936	242.60	241.20	189.50	51469	44995						
	400			446.99	25674	426.95	28715	301.31	29000	309.10	6280	3880	12254	242.60	241.30	189.50	51454	45000						
	500			446.99	25674	426.95	29835	301.57	30000	309.35	6880	3880	12643	242.70	241.40	189.50	51660	46600						
	600			446.97	25575	426.95	29975	301.60	30000	309.60	6880	3880	13031	242.80	241.60	189.50	51885	46700						< Open from Grand F
	700	501.68	34361	446.96	25510	427.00	31655	301.60	30000	309.85	6880	3880	13384	242.90	241.65	190.00	52210	48250						broken ice, then
	800			448.15	31794	426.90	27480	301.80	31000	310.10	6800	3880	12678	242.90	241.75	190.50	52797	49330						
	815																							< Tobique started
	853																							
	900			450.63	48442	426.90	30955	301.83	31000	310.35	7380	4380	12290	242.90	241.80	190.50	52637	50900						
	930																							
	1000			452.07	58195	426.70	29065	302.62	36000	310.45	6620	5420	13420	243.00	241.80	191.00	53351	52300						< Open from Grand F
	1100			452.67	62295	426.50	27085	302.29	34000	310.65	7820	5420	13490	243.10	241.85	191.00	55176	52300						broken ice, then
	1200			453.69	69188	426.70	40385	302.29	34000	310.85	8400	10000	13384	243.30	241.90	191.00	57094	53875						Open spot below
	1300			454.22	72929	426.60	32600	302.65	36000	310.95	7730	6530	12502	243.30	242.00	191.50	62273	52700						Andover bridge.
	1330																							< Open from Grand F
	1400			455.21	79884	426.60	37340	302.88	37000	311.00	7830	7230	11901	243.40	242.00	191.50	59274	60865						broken ice,then O
	1500	502.69	39868	455.98	85308	426.60	37940	302.98	38000	311.05	7130	6530	12713	243.50	242.00	192.00	59313	64345						< Aroostook River
	1545																							
	1600			454.94	77979	426.70	43275	303.31	40000	311.20	8330	6530	14055	243.20	241.70	192.50	60384	68000	1	< Morrell Siding	< 3 miles above Morrell Siding at Medford			
	1640																							
	1700			455.88	84567	426.80	43275	303.64	42000	311.25	7735	7135	15998	243.10	241.50	193.00	63174	70340						
	1715																							< Holding 8 ft. of
	1800			456.19	86801	427.00	48615	303.64	42000	311.45	9650	7250	14691	243.20	241.30	192.50	66630	70340						open below Grand
	1840																							
	1900			456.33	87766	426.95	42260	303.97	44000	311.45	8270	8270	14832	243.10	241.20	192.50	68235	70270						
	1920																							
	2000			456.47	88843	426.85	40650	303.97	44000	311.45	8480	8480	15256	243.20	241.30	192.50	70668	70340						
	2015																							< Open 2 miles abov
	2100			456.62	89885	426.75	42010	304.20	45000	311.45	8480	8480	17234	243.40	241.30	192.50	72803	72500						Jammed ~ 4.5 mile
	2135																							Road flooded at
	2200			456.67	90275	426.75	45345	304.20	45000	311.45	8480	8480	16351	243.20	241.40	193.00	75529	74490						
	2205																							
	2300	503.32	43502	456.52	89194	426.75	45945	304.29	46000	311.45	8960	8960	17234	243.30	241.20	193.00	76622	70000						
	2400			456.47	88869	426.95	53215	304.39	47000	311.50	9400	8800	18117	247.70	240.85	193.00	78343	75860						< Broken ice in Per

TABLE A.1a

GRAND FALLS TO BEECHWOOD CHRONOLOGY

BEECHWOOD NBEPC			OBSERVED JAM LOCATION				
TAILRACE EL (Measured in ft)	INFLOW (Calc 4 in ft^3/s)	OUTFLOW (Calc 3 in ft^3/s)	JAM POSITION	HEAD	TAIL	TIME	COMMENTS
							< Open from Grand Falls down 4 km. Aroostook River open 1 km down from Tinker
						1800	< Tinker started spilling
188.50	35215	29500				100	
188.50	27069	29500				200	
188.50	25770	29500				300	
188.50	29745	29500				400	
188.50	35738	29700				500	
188.50	38433	29701				600	
188.50	38053	29800				700	
188.50	37848	29800				800	
						830	< Beechwood started spilling.
188.50	37398	32100				900	
198.50	37457	31515				1000	
188.50	38538	34040				1100	
189.00	38663	34970				1200	
189.00	38984	34980				1300	
189.00	39452	36650				1400	
189.00	39891	36660				1500	< Open from Grand Falls down 7 km, then 1 km of broken ice.
189.00	41247	37430				1600	
						1630	
189.00	42684	37430				1700	
189.00	43064	39600				1800	
189.00	44069	41160				1900	
189.00	47090	41160				2000	
189.00	49281	43080				2100	
						2140	
189.50	49982	43105				2200	
189.50	50386	44845				2300	
189.50	50777	44995				2400	
189.50	51095	44995				100	
189.50	51341	44995				200	
189.50	51469	44995				300	
189.50	51454	45000				400	
189.50	51660	46600				500	
189.50	51885	46700				600	< Open from Grand Falls down 19 km, then 6 km of broken ice, then solid to Beechwood.
190.00	52210	48250				700	
190.50	52797	49330				800	
						815	< Tobique started spilling.
						853	
190.50	52637	50900				900	
191.00	53351	52300				1000	< Open from Grand Falls down 18 km, then 3 km of broken ice, then 5 km open, then 6 km of broken ice, Open spot below Tobique dam, small channel to Perth-Andover bridge.
191.00	55176	52300				1100	
191.00	57094	53875				1200	
191.50	62273	52700				1300	< Open from Grand Falls down 19 km, then 3 km of broken ice, then 0.5 km open, then 6 km of broken ice.
						1330	< Aroostook River open from Caribou to Ft. Fairfield.
191.50	59274	60865				1400	
192.00	59313	64345				1500	
						1545	
192.50	60384	68000	1	< Morrell Siding	< 3 miles above Morrell Siding at Medford	1600	< Jam in Tilley area (Morrell Siding).
						1640	
193.00	63174	70340				1700	
						1715	< Holding 8 ft. of water and over road. 25 km open below Grand Falls.
192.50	66630	70340				1800	
						1840	
192.50	68235	70270				1900	
						1920	
192.50	70668	70340				2000	
						2015	< Open 2 miles above Baker's Ferry (or Morrell Siding). Jammed ~ 4.5 miles below Morrell Sidings. Road flooded at Baker's Ferry.
192.50	72803	72500				2100	
						2135	
193.00	75529	74490				2200	
						2205	
193.00	76622	70000				2300	
193.00	78343	75860				2400	< Broken ice in Perth-Andover region.

DATE	TIME	FORT KENT NBEPC ELEVATION (Measured in ft)	FORT KENT NBEPC DISCHARGE (Calc. 1 in ft^3/s)	EDMUNDSTON WSC-01AD004 ELEVATION (Measured in ft*)	EDMUNDSTON WSC-01AD004 DISCHARGE (Calc. 1 in ft^3/s*)	EDMUNDSTON WSC-01AD004 HEADPOND EL. (Measured in ft)	EDMUNDSTON WSC-01AD004 INFL
01-Apr-87							
	15						
	30						
	45						
	50						
	100			456.55	89426	426.95	4854
	115						
	120						
	130						
	145						
	200			456.70	90459	427.05	5367
	215						
	230						
	245						
	300			456.57	89587	426.85	432
	310						
	315						
	320						
	330						
	345						
	400			456.90	91882	426.65	4287
	415						
	430						
	445						
	500			456.93	92112	427.20	7360
	515						
	530						
	545						
	600			457.01	92662	427.15	5320
	615						
	630						
	645						
	700	503.78	46262	456.48	88895	427.20	5658
	715						
	730						
	800			454.69	76189	427.15	5600
	815						
	830						
	845						
	900			454.24	73044	427.50	7322
	915						
	930						
	945						
	1000			453.97	71207	426.50	3824
	1015						
	1030						
	1045						
	1050						
	1100			453.83	70221	426.20	636
	1115						
	1130						
	1200			454.04	71644	426.50	8450
	1215						
	1230						
	1245						
	1300			454.33	73710	425.30	3140
	1315						
	1330						
	1345						
	1400			454.66	76005	426.00	9441
	1415						
	1430						
	1445						
	1500	506.54	64727	454.99	78300	425.00	4718
	1515						
	1530						
	1545						
	1600			455.32	80550	425.25	9043
	1615						
	1630						

TABLE A.1b

GRAND FALLS TO BEECHWOOD CHRONOLOGY

TIME	FORT KENT NBEPC ELEVATION (Measured in ft)	FORT KENT NBEPC DISCHARGE (Calc.1 in ft³/s)	EDMUNDSTON WSC-01AD004 ELEVATION (Measured in ft*)	EDMUNDSTON WSC-01AD004 DISCHARGE (Calc.1 in ft³/s*)	GRAND FALLS NBEPC HEADPOND EL. (Measured in ft)	GRAND FALLS NBEPC INFLOW (Calc.2 in ft³/s)	GRAND FALLS WSC-01AF002 ELEVATION** (Measured in ft*)	GRAND FALLS WSC-01AF002 OUTFLOW (Calc.1 in ft³/s)	TOBIQUE RIVER NBEPC HEADPOND EL. (Measured in ft)	TOBIQUE RIVER NBEPC TAILRACE EL. (Measured in ft)	TOBIQUE RIVER NBEPC INFLOW (Calc.2 in ft³/s)	TOBIQUE RIVER NBEPC OUTFLOW (Calc.3 in ft³/s)	ARoostook River WSC 01AG003 OUTFLOW (Calc.1 in ft³/s*)	PERTH-NBEPC ELEVATION (Measured in ft)	BEECHWOOD NBEPC HEADPOND EL. (Measured in ft)	BEECHWOOD NBEPC TAILRACE EL. (Measured in ft)	BEECHWOOD NBEPC INFLOW (Calc.4 in ft³/s)	BEECHWOOD NBEPC OUTFLOW (Calc.3 in ft³/s)	JAM POSITION	OBSERVED JAM LOCATION HEAD	OBSERVED JAM LOCATION TAIL	OBSERVED JAM LOCATION TIME	COMMENTS
87																							
15														248.20								5	< Perth at 248 and increasing rapidly. (Jam has moved below Perth-Andover)
30														249.00	243.20							15	
45														248.90	243.60							30	
50																						45	
100		456.55	89426	426.95	48545	304.72	49000	311.15	9040	8440	17587	249.10	243.15	194.50	79673	90700					50	
115												249.30	242.75								100	
120																					115	
130												249.50	243.55								120	
145												249.50	243.35								130	
200		456.70	90459	427.05	53675	304.98	50000	311.15	8520	8520	15680	249.80	243.25	194.00	79861	96200					145	
215												249.70	243.20								200	
230												250.80	243.30								215	
245												250.70	243.05								230	
300		456.57	89587	426.85	43280	304.98	50000	311.70	10420	8620	17905	250.90	242.20	194.50	79786	95200					245	
310																					300	< (Jam below Perth is storing water and head pond level dropping)
315												251.20	242.00								310	
320																					315	
330												251.40	241.85								320	
345												251.90	241.75								330	
400		456.90	91882	426.65	42875	304.88	50000	311.85	10900	9100	20271	251.90	241.40	194.50	82899	94500					345	
415												252.10	241.20								400	
430												252.50	241.10								415	
445												252.80	241.00								430	
500		456.93	92112	427.20	73600	305.61	54000	311.95	10800	9600	19953	252.60	241.00	194.00	87008	90200					445	
515												252.50	240.90								500	
530												252.50	240.80								515	
545												252.30	240.75								530	< Ice let go at Caribou on Aroostook River, predicted to arrive at Tinker in 3 hours.
600		457.01	92662	427.15	53205	305.70	55000	312.05	10000	8800	20483	251.10	240.70	194.00	88099	93000					545	
615												249.50	241.85								600	
630												249.10	243.00				5.1	< Kilburn			615	
645												248.30	242.90								630	< 6 km of jammed ice in area.
700	503.78	46262	456.48	88895	427.20	56580	305.64	55000	312.25	11580	9180	28923	248.30	243.15	196.00	89610	110200				645	
715													248.30	242.30							700	< Ice at Perth gone down into headpond.
730													248.40	242.70							715	
800			454.69	76189	427.15	56005	306.10	58000	312.35	10900	9700	27687	248.00		196.25	97660	112000				730	
815													248.00	242.75							800	< Open from Grand Falls to 6 km below Perth bridge, then 6 km broken ice, then sheet ice to Beechwood. Ice running at Inman Crossing.
830													248.10	242.50				6	< Muniac		815	
845													248.10	242.45							830	
900			454.24	73044	427.50	73220	306.69	60000	312.95	17000	9800	18117	248.40	242.35	196.00	99565	113000				845	
915													248.10	242.80							900	< (Drawdown at Grand Falls head pond started)
930													247.70	242.70							915	
945													247.50	242.60							930	
1000			453.97	71207	426.50	38245	308.03	74000	312.05	15380	14180	29700	247.50	242.20	197.50	98956	121600				945	
1015													247.40	241.90							1000	
1030													247.30	242.25							1015	
1045													247.40	241.80							1030	
1050																					1045	
1100			453.83	70221	426.20	63640	308.03	74000	313.00	15940	16540	24862	247.50	241.80	197.50	107940	139200				1050	
1115													247.50	241.40							1100	
1130													247.30	241.25							1115	< Broken ice moving past Upper Kent Airfield
1200			454.04	71644	426.50	84500	308.13	74000	313.00	18455	18455	23732	247.40	241.20	198.00	114339	140100				1130	< Open from Grand Falls to Muniac Stream, then 4.5 km slow moving broken ice, then sheet ice to Beechwood. (Note: Jam not stationary)
1215													247.30	241.00							1200	
1230													247.40	241.00							1215	
1245													247.50	240.00							1230	
1300			454.33	73710	425.30	31400	307.64	70000	312.55	13870	19270	19070	247.50	240.00	198.00	119709	138370	9	< Upper Guisiguit Brook		1245	
1315													247.50	239.45							1300	< Jam observed at Upper Guisiguit Brook
1330													247.50	239.30							1315	
1345													247.40	239.20							1330	
1400			454.66	76005	426.00	94415	307.84	72000	312.20	15070	19270	19529		239.10	198.00	121020	135700				1345	
1415													247.50	239.20							1400	
1430													247.50	239.25							1415	
1445													247.50	239.20							1430	
1500	506.54	64727	454.99	78300	425.00	47185	308.66	79000	311.95	15570	18570	25462	247.30	239.20	198.00	122608	131600				1445	
1515													247.40	239.20							1500	
1530													247.50	239.25							1515	
1545													247.50	239.30							1530	
1600			455.32	80550	425.25	90435	309.05	82000	311.80	15970	17770	26557	247.50	239.40	198.00	125465	129300				1545	
1615													247.50	239.30							1600	
1630													247.60	239.20							1615	
																					1630	

DATE	TIME	FORT KENT NBEPC ELEVATION (Measured in ft)	FORT KENT NBEPC DISCHARGE (Calc.1 in ft³/s)	EDMUNDSTON WSC-01AD004 ELEVATION (Measured in ft)	EDMUNDSTON WSC-01AD004 DISCHARGE (Calc.1 in ft³/s*)	GRAND FALLS NBEPC HEADPOND EL. (Measured in ft)	GRAND FALLS WSC-01AF002 INFLOW (Calc.2 in ft³/s)	GRAND FALLS WSC-01AF002 ELEVATION** (Measured in ft*)	GRAND FALLS WSC-01AF002 OUTFLOW (Calc.1 in ft³/s)	GRAND FALLS WSC-01AF002 HEADPOND EL. (Measured in ft)	TOBIQUE RIVER NBEPC TAILRACE EL. (Measured in ft)	TOBIQUE RIVER NBEPC INFLOW (Calc.2 in ft³/s)	TOBIQUE RIVER NBEPC OUTFLOW (Calc.3 in ft³/s)	AROOSTOOK RIVER WSC 01AG003 OUTFLOW (Calc.1 in ft³/s*)	PERTH-NBEPC ELEVATION (Measured in ft)	PERTH-NBEPC HEADPOND EL. (Measured in ft)	BEECHWOOD NBEPC TAILRACE EL. (Measured in ft)	BEECHWOOD NBEPC INFLOW (Calc.4 in ft³/s)	BEECHWOOD NBEPC OUTFLOW (Calc.3 in ft³/s)	JAM POSITION	HEAD	JA
	1645															247.60	239.25						
	1700			455.66	83075	424.05	46270	309.08	83000	311.80		16450	16450	22849		247.50	239.25	197.50	127621	131100			
	1715															247.50	239.16						
	1730															247.50	239.15						
	1745															247.60	239.20						
	1800			456.01	85699	423.25	58020	308.72	80000	311.80		16450	16450	56857		247.50	239.20	197.50	134045	133500			
	1815															247.60	239.15						
	1830															247.80	239.15						
	1845															248.00	239.25						
	1900			456.34	87766	423.55	88345	308.79	80000	311.90		17750	16550	59682		248.10	239.30	198.50	161407	139200			
	1915															248.10	239.40						
	1930															248.20	239.90						
	1945															248.30	239.55						
	2000			456.66	90161	424.75	126955	312.00	107000	312.00		17750	16550	51207		248.40	239.55	199.00	170095	148400			
	2015															248.50	239.40						
	2030															248.60	239.40						
	2045															248.60	239.40						
	2100			456.67	90390	425.45	148875	312.53	112000	312.15		18350	16550	46969		248.70	239.45	199.00	166489	149100			
	2115															248.80	239.50						
	2130															248.90	239.40						
	2145															248.90	239.40						
	2200			456.61	89931	426.50	159050	314.07	125000	312.15		17870	17870	43791		249.10	239.25	199.00	171447	148300			
	2215															249.30	239.25						
	2230															249.50	239.20						
	2245															249.70	239.20						
	2300	509.35	86212	456.67	90390	427.15	152980	314.73	131000	312.05		16970	18170	43084		249.90	239.20	199.00	180108	147900			
	2315															250.10	239.40						
	2330															250.20	241.50						
	2345															250.20	241.80						
	2400			456.83	91309	427.60	137840	315.45	138000	312.05		7390	17390	40965		250.20	240.40	200.00	188882	164200			
02-Apr-87	15																						
	30																						
	45															250.90	238.70						
	100			457.04	92915	427.95	143185	315.97	143000	312.45		2229.	17490	39906		251.00	239.35						
	115									312.50						251.40	239.20	200.00	195208	164200			
	130									312.50						251.90	239.05						
	145									312.55						252.00	238.80						
	200			457.28	94622	427.70	141515	315.81	141000	312.65		2205	19640	39906		252.20	238.50						
	215									312.95						252.20	238.60	200.50	201186	176400			
	230									312.50						252.70	238.50						
	245									312.60						252.90	238.30						
	300			457.52	96228	427.65	141515	315.81	142000	312.65		23790	22590	39906		252.70	237.90						
	315									312.45						252.70	237.75	201.50	208799	188000			
	330									312.25						252.70	237.55						
	345									312.25						252.80	237.40						
	400			457.76	98065	427.50	137840	315.45	138000	312.25		22680	28680	40259		252.80	237.40	201.50	214537	189300			
	415										258.00						237.20						
	430									311.85							236.95						
	445									311.85							236.75						
	500			457.99	99000	427.50	135840	315.25	136000	311.85	258.00	23790	28590	40612			236.45	202.00	219347	195450			
	515									311.50							236.00						
	530									311.50	258.00						235.70						
	545									311.45							235.20						
	600			458.22	100500	427.45	136170	315.28	136000	311.30	258.80	22630	28630	41319			234.75	201.50	219095	184725			
	605																						
	615									311.15							234.25						
	620																						
	630									311.10	260.40						233.60						
	645									311.00							233.35						
	655																						
	700	511.54	104918	458.45	102300	427.50	134835	315.15	135000	311.00	261.40	2413(	28330	42025			233.25	200.00	217784	177250			
	715									310.95							233.00						
	730									310.80							233.00						
	745									310.80							232.80						
	800			458.67	103500	427.50	136170	315.28	136000	310.80	262.60	2272(	25720	43084			232.80	200.00	216479	169280			
	815									310.80							233.00						
	830									310.70	262.80						232.95						
	845									310.65							233.50						
	850																						

TABLE A.1c

GRAND FALLS TO BEECHWOOD CHRONOLOGY

...POND EL. (Measured in ft)	BEECHWOOD NBEPC: TAILRACE EL. (Measured in ft)	BEECHWOOD NBEPC: INFLOW (Calc. 4 in ft^3/s)	BEECHWOOD NBEPC: OUTFLOW (Calc. 3 in ft^3/s)	OBSERVED JAM LOCATION: JAM POSITION	OBSERVED JAM LOCATION: HEAD	OBSERVED JAM LOCATION: TAIL	TIME	COMMENTS
							1645	
	197.50	127621	131100				1700	< Tinker dam started spilling Aroostook River ice.
							1715	
							1730	
							1745	
	197.50	134045	133500				1800	< *(Maximum drawdown of Grand Falls head pond achieved prior to ice sluicing)*
							1815	
							1830	< St. Leonard Jam let go.
							1845	
	198.50	161407	139200				1900	< Running full of ice at Perth-Andover
							1915	
							1930	
							1945	
	199.00	170095	148400				2000	< Grand Falls started to spill ice (continued through 1100 hrs April 2). All sluice gates wide open.
							2015	
							2030	
							2045	
	193.00	166489	149100				2100	
							2115	
							2130	
							2145	
	199.00	171447	148300				2200	
							2215	
							2230	
							2245	
	199.00	180108	147900				2300	
							2315	
							2330	< Jam at Upper Kent consolidated.
							2345	and stopped. *(Sudden level rise at beechwood implies last jam movement released water)*
	200.00	188882	164200				2400	
							15	< Water over road at Lower Perth.
							30	< Heavy drawdown started at Beechwood - 8 of 9
							45	gates raised from 6 ft to 12 ft opening.
	200.00	195208	164200				100	
							115	
							130	
							145	
	200.50	201186	176400				200	< Beechwood gates raised to 14 ft opening. Grand Falls
							215	ice and water arriving and building above jam. *(Tobique*
							230	*Headpond drawdown started)*
							245	
	201.50	208799	188000				300	
							315	
							330	
							345	
	201.50	214537	189300				400	
							415	
							430	
							445	
	202.00	219347	195450				500	< Ice jamming under Perth-Andover railroad bridge.
							515	
							530	< *(Level at railroad bridge is ~256 lower*
							545	*chord)*
	201.50	219095	184725				600	< Railroad bridge on Andover side reported moved.
							605	3 gates cleared of water surface at Beechwood.
							615	Ice being stopped by railroad bridge.
							620	
							630	
							645	
							655	
	200.00	217784	177250				700	< 4 gates cleared at Beechwood.
							715	
							730	
							745	< Photos show open water and well rotted thermal cover
								just above Beechwood.
	200.00	216479	169280				800	< 5 gates cleared at Beechwood.
							815	
							830	
							845	< *(Beechwood head pond level rose - jam re-*
							850	*leased water)*

DATE	TIME	FORT KENT NBEPC ELEVATION (Measured in ft)	FORT KENT NBEPC DISCHARGE (Calc. 1 in ft³/s)	EDMUNDS WSC-01AD ELEVATION (Measured in ft)	EDMUNDS WSC-01AD DISCHARGE (Calc. 1 in ft³/s)	EDMUNDS WSC-01AD HEA
	900			458.88	104900	427.55
	915					
	930					
	934					
	935					
	938					
	941					
	945					
	955					
	1000			459.07	106400	427.65
	1015					
	1030					
	1045					
	1100			459.25	107900	427.70
	1115					
	1130					
	1138					
	1140					
	1145					
	1200			459.43	109300	427.70
	1205					
	1215					
	1230					
	1245					
	1300			459.55	109900	427.70
	1330					
	1335					
	1345					
	1350					
	1400			459.66	110250	427.85
	1430					
	1452					
	1500	512.46	113292	459.78	111000	427.90
	1600			459.86	111750	427.95
	1635					
	1700			459.94	112250	428.05
	1715					
	1800			460.01	112750	428.20
	1900			460.04	113000	428.23
	2000			460.05	113250	428.35
	2100			460.08	113250	428.40
	2200			460.15	113750	428.65
	2300	512.22	111050	460.16	114000	428.85
	2400			460.15	114000	428.90
03-Apr-87	25					
	100			460.15	113750	428.95
	200			460.11	113500	428.90
	300			460.07	113250	428.85
	340					
	400			459.99	112750	428.80
	415					
	427					
	439					
	445					
	500			459.91	112000	428.85
	555					
	600			459.83	111500	428.75
	618					
	639					
	651					
	700	511.85	107706	459.76	111000	428.75
	720					

TABLE A.1d

GRAND FALLS TO BEECHWOOD CHRONOLOGY

TIME	FORT KENT NBEPC ELEVATION (Measured in ft)	FORT KENT NBEPC DISCHARGE (Calc. 1 in ft³/s)	EDMUNDSTON WSC-01AD004 ELEVATION (Measured in ft*)	EDMUNDSTON WSC-01AD004 DISCHARGE (Calc. 1 in ft³/s*)	GRAND FALLS NBEPC HEADPOND EL. (Measured in ft)	GRAND FALLS NBEPC INFLOW (Calc. 2 in ft³/s)	GRAND FALLS WSC-01AF002 ELEVATION** (Measured in ft*)	GRAND FALLS WSC-01AF002 OUTFLOW (Calc.1 in ft³/s)	TOBIQUE RIVER NBEPC HEADPOND EL. (Measured in ft)	TOBIQUE RIVER NBEPC TAILRACE EL. (Measured in ft)	TOBIQUE RIVER NBEPC INFLOW (Calc. 2 in ft³/s)	TOBIQUE RIVER NBEPC OUTFLOW (Calc. 3 in ft³/s)	AROOSTOOK RIVER WSC 01AG003 OUTFLOW (Calc. 1 in ft³/s*)	PERTH-NBEPC ELEVATION (Measured in ft)	BEECHWOOD NBEPC HEADPOND EL (Measured in ft)	BEECHWOOD NBEPC TAILRACE EL. (Measured in ft)	BEECHWOOD NBEPC INFLOW (Calc. 4 in ft³/s)	BEECHWOOD NBEPC OUTFLOW (Calc.3 in ft³/s)	BEECHWOOD NBEPC JAM POSITION	OBSERVED JAM LOCATION HEAD	OBSERVED JAM LOCATION TAIL	TIME	COMMENTS
900		458.88	104900	427.55	137175	315.38	137000	310.60	263.00	22050	23850	44497		233.40	199.20	214529	186950				900	< Grand Falls still sluicing ice. Some Beechwood ice started through 5 open gates. Andover railroad bridge failed. Perth-Andover levels surged upward after failure(~260 near bridge). Jam at bridge was ~1200 to 1500 ft. long.
915								310.00						233.50							915	
930								310.45	262.00					233.50						< 5 miles below Perth-Andover	930	
934																					934	< Ice moving above Beechwood.
935																					935	< Headpond rising rapidly.
938																					938	< 2 ft. rise in 3 minutes.
941																					941	< another 2 ft. in 3 minutes
945								310.45	261.20					242.20	200.60						945	
955																					955	< Beechwood started spilling ice. Packed ice 0.5 mile above Beechwood.
1000		459.07	106400	427.65	137840	315.45	138000	310.10	260.00	16920	18760	45203		242.70	201.80	212593	284215				1000	< 6 gates cleared at Beechwood.
1015								310.15	258.00					243.05							1015	
1030						315.55	139000	310.15	257.50					242.75			309830				1030	
1045								310.15	257.00					241.90							1045	
1100		459.25	107900	427.70	138510	315.51	138000	310.00	256.80	13920	19320	44144		241.40	203.20	209917	281580				1100	< Grand Falls stopped sluicing ice. All Beechwood ice now moving.
1115								309.90	256.00					240.70							1115	< Photos show moving broken ice (~15% coverage) 1 mile below Perth Andover.
1130								309.90	255.80					240.65	206.40						1130	< Photos show moving broken ice (~15% coverage) 1 mile above Perth Andover and at Tobique. Tobique headpond still has thermal ice cover. Water level at railroad bridge ~at top of piers.
1138																					1138	< 2 miles of broken ice above Beechwood.
1140																					1140	
1145								309.90	255.50					240.30							1145	
1200		459.43	109300	427.70	140180	315.68	140000	309.80	255.50	15690	18090	44144		240.10	202.50	209787	281580				1200	
1205																					1205	
1215								309.80	255.50					240.70							1215	
1230								309.65	255.00					240.40							1230	
1245								309.60	254.50					240.40						< Irving Piers	1245	
1300		459.55	109900	427.70	142850	315.94	143000	309.60	254.00	13900	16330	44144		240.40	201.80	209273	281580				1300	
1330								309.90						240.60							1330	
1335																					1335	
1345																					1345	
1350																					1350	
1400		459.66	110250	427.85	142515	315.91	143000	310.05	253.00	19160	13760	44144		240.00	202.00	207975	296020				1400	< All ice reported passed through Beechwood. Units started up - over next 40 minutes trash racks clogged with ice.
1430								310.55	253.00					239.20							1430	
1452																					1452	
1500	512.46	113292	459.78	111000	427.90	144520	316.11	145000	310.65	252.00	24520	13720	44144		239.50	200.00	207765	245600				1500	
1600			459.86	111750	427.95	145855	316.24	146000	311.00		20920	13720	44497		238.90	198.50	208880	225260				1600	
1635																						1635
1700			459.94	112250	428.05	147860	316.43	148000	311.53		19720	16120	44850		238.60	198.50	211516	223510				1700	
1715																						1715
1800			460.01	112750	428.20	148195	316.47	148000	312.00		21040	15640	45203		238.20	198.50	214357	221550				1800	
1900			460.04	113000	428.23	148195	316.47	148000	312.05		21370	20770	45556	251.60	238.20	198.50	217293	221550				1900	
2000			460.05	113250	428.35	148860	316.53	149000	312.15		21970	20770	45910		237.80	199.50	221771	226475				2000	
2100			460.08	113250	428.40	152200	316.86	152000	312.05		20370	21570	45910		237.70	199.50	223474	225445				2100	
2200			460.15	113750	428.65	154540	317.06	155000	312.00		20920	21570	46263		237.50	199.50	225156	229205				2200	
2300	512.22	111050	460.16	114000	428.85	155540	317.19	156000	311.95		20970	21570	45910		237.10	201.00	226666	238425				2300	
2400			460.15	114000	428.90	155875	317.22	156000	311.90		20570	21170	46616		236.75	201.00	227964	231660				2400	
25																					25	
100			460.15	113750	428.95	155875	317.22	156000	311.75		19010	20810	46969		236.60	201.00	229201	229535				100	
200			460.11	113500	428.90	157545	317.38	158000	311.70		18980	19580	47322		236.40	201.00	229894	234175				200	
300			460.07	113250	428.85	156875	317.32	157000	311.60		18120	19320	47322		236.30	201.50	229370	233025				300	
340																					340	
400			459.99	112750	428.80	155540	317.19	156000	311.50		18030	19230	46969		235.95	201.50	229280	235500				400	
415																					415	
427																					427	
439																					439	
445																					445	
500			459.91	112000	428.85	157545	317.38	157000	311.40		17475	18675	46969		235.90	201.50	229004	234530				500	
555																					555	
600			459.83	111500	428.75	154870	317.12	155000	311.30		16655	17855	46969		235.50	202.00	227570	235200				600	
618																					618	
639																					639	
651																					651	
700	511.85	107706	459.76	111000	428.75	156210	317.25	156000	311.30		15830	15830	46969		235.40	202.00	226238	234235				700	
720																					720	

DATE	TIME	FORT KENT NBEPC ELEVATION (Measured in ft)	FORT KENT NBEPC DISCHARGE (Calc. 1 in ft³/s)	EDMUNDSTON WSC-01AD004 ELEVATION (Measured in ft*)	EDMUNDSTON WSC-01AD004 DISCHARGE (Calc. 1 in ft³/s*)	GRAND FALLS NBEPC HEADPOND EL. (Measured in ft)	GRAND FALLS NBEPC INFLOW (Calc. 2 in ft³/s)	GRAND FALLS WSC-01AF002 ELEVATION** (Measured in ft*)	GRAND FALLS WSC-01AF002 OUTFLOW (Calc.1 in ft³/s)	TOBIQUE RIVER NBEPC HEADPOND EL. (Measured in ft)	TOBIQUE RIVER NBEPC TAILRACE EL. (Measured in ft)	TOBIQUE RIVER NBEPC INFLOW (Calc.2 in ft³/s)	TOBIQUE RIVER NBEPC OUTFLOW (Calc.3 in ft³/s)	AROOSTOOK RIVER WSC 01AG003 OUTFLOW (Calc. 1 in ft³/s*)	PERTH-NBEPC ELEVATION (Measured in ft)	BEECHWOOD NBEPC HEADPOND EL. (Measured in ft)	BEECHWOOD NBEPC TAILRACE EL. (Measured in ft)	BEECHWOOD NBEPC INFLOW (Calc. 4 in ft³/s)	BEECHWOOD NBEPC OUTFLOW (Calc.3 in ft³/s)	JAM POSITION	HEAD
	743																				
	756																				
	800			459.69	110500	428.70	155875	317.22	156000	311.15		1432(	16160	46969		235.00	202.00	224520	229615		
	830																				
	840																				
	900			459.61	110300	428.60	155540	317.19	156000	311.20		1616(	15560	46616		234.80	202.00	224215	227320		
	915																				
	1000			459.54	108640	428.35	153535	316.99	154000	311.20		155(	15560	46616		234.40	202.00	223218	226850		
	1015																				
	1030																				
	1100			459.46	109500	428.35	153200	316.96	153000	311.(			12570	45910	247.10	234.35	202.00	221475	226850		
	1110																				
	1200			459.37	108900	428.35	154540	317.06	155000	311.40		14370	12570	45910	246.90	234.45	202.00	218733	223620		
	1233																				
	1300			459.24	107900	428.15	154540	317.06	155000	311.60		14970	12570	46263		234.45	202.00	218005	220755		
	1330																				
	1345																				
	1400			459.16	107000	428.05	152535	316.89	153000	311.75		15570	12570	44497		234.40	202.00	217594	219635		
	1450																				
	1500	511.09	100855	459.07	106400	428.05	152810	316.83	153000	311.85		13770	12570	44497		234.40	202.00	216630	219635		
	1600			458.97	105500	428.05	151535	316.79	151000	311.95		14060	12860	45910		234.20	201.50	216073	217190		
	1700			458.87	104700	428.00	148195	316.47	148000	312.10		14920	13120	45910		234.30	201.50	216118	214800		
	1800			458.76	104100	428.05	147525	316.40	147000	312.25		14920	13120	47675		234.30	201.50	215687	214800		
	1900			458.66	103500	428.00	148195	316.47	148000	312.45		15520	13120	46616	246.70	234.75	200.50	215258	212865		
	1905																				
	1920																				
	2000			458.56	102900	427.90	146525	316.30	146000	312.55		16250	15050	46263		234.90	200.50	213734	213880		
	2030																				
	2100			458.46	102300	427.80	145855	316.24	146000	312.55		15690	15690	46263	246.70	234.90	200.50	214298	213880		
	2200			458.36	101700	427.75	145190	316.17	145000	312.55		15690	15690	46263		235.00	200.50	213922	214200		
	2300	510.31	94070	458.23	100750	427.65	143185	315.97	143000	312.55		15690	15690	45910		235.00	200.50	212810	214200		
	2400			458.10	99750	427.50	142185	315.88	142000	312.55		15690	15690	45910		235.00	200.50	211571	214700		
04-Apr-87	100			457.97	99000	427.40	140515	315.71	141000	312.45		14490	15690	45910		234.80	200.50	210219	211815		
	200			457.84	98556	427.35	141515	315.81	142000	312.45		15730	15730	45556		234.95	200.00	209255	212920		
	300			457.70	97605	427.20	136170	315.28	136000	312.25		13330	15730	45556		235.00	200.00	207053	210745		
	400			457.56	96688	427.15	136170	315.28	136000	312.25		14550	14550	45203		234.95	200.00	205844	210745		
	500			457.42	95540	427.10	135170	315.19	135000	312.30		14250	13650	45203		234.80	200.00	202457	208745		
	550																				
	600			457.27	94622	426.90	135170	315.19	135000	312.40		14170	12970	44850		234.80	200.00	199864	206440		
	700	509.29	85734	457.14	93647	426.80	133835	315.06	133000	312.40		12970	12970	44497		234.90	199.50	197690	203620		
	710																				
	800			457.02	92685	426.70	131950	314.86	132000	312.50		13150	11950	44497		235.00	199.00	196198	201490		
	900			456.91	91997	426.95	130755	314.73	131000	312.55		12550	11950	43084		235.00	199.00	194074	201490		
	928																				
	1000			456.75	90849	426.55	130755	314.73	131000	312.60		12550	11950	43084	245.40	234.90	199.00	192117	200500		
	1100			456.70	90390	426.40	129855	314.63	130000	312.65		12550	11950	43084		235.00	199.00	190981	198590		
	1200			456.45	88738	426.20	127755	314.40	128000	312.70		12550	11950	43084	245.30	235.30	198.50	190095	190960		
	1300			456.32	87766	425.85	126245	314.24	126000	312.75		12550	11950	42731	245.60	235.45	198.50	189004	192690		
	1400			456.19	86847	425.80	123880	313.97	124000	312.80		12550	11950	42378	245.50	235.60	198.20	187237	189425		
	1500	508.22	77391	456.06	85929	425.75	123880	313.97	124000	312.75		13050	13650	42025	245.50	235.80	198.00	186018	188145		
	1600			455.94	84941	425.50	122000	313.74	122000	312.60		11850	13650	41672	245.10	235.90	198.00	185125	189400		
	1626																				
	1700			455.81	83994	425.45	120620	313.58	121000	312.65		11850	12970	41319	245.10	235.90	198.00	183462	189700		
	1800			455.68	83075	425.45	119805	313.48	120000	312.65		12250	12250	37434	245.10	235.90	198.00	180138	189400		
	1900			455.56	82386	425.25	118450	313.32	118000	312.60		11330	11930	40965	244.80	235.90	198.00	175217	186745		
	2000			455.44	81468	425.20	117905	313.25	118000	312.60		11390	11290	45910	244.50	235.90	198.00	177563	182965		
	2100			455.32	80550	425.10	116280	313.05	116000	312.70		11950	10750	42731	244.60	235.80	198.00	179528	178685		
	2200			455.20	79861	425.00	115195	312.92	115000	312.85		12550	10750	40612	244.60	236.00	197.50	174784	174250		
	2300	507.33	70590	455.08	78943	424.85	114380	312.82	114000	312.80		10690	11290	39906	244.60	236.35	196.50	171424	172280		
	2400			454.96	78025	424.80	113020	312.66	113000	312.85		11890	11290	39200	244.60	236.45	196.50	170141	172290		
05-Apr-87	100			454.84	77337	424.65	112480	312.59	112000	312.90		11890	11290	38493	244.60	236.50	196.50	168360	173000		
	200			454.72	76418	424.55	111390	312.46	111000					38140				166682	167745		
	300			454.61	75730					312.90		11290	11290	37434	244.60	236.60	196.50	165344			
	400			454.51	75040	424.50	110305	312.33	110000	312.95		11290	11290	37081	244.50	236.80	196.50	163951	166825		
	500			454.41	74352	424.40	109765	312.27	110000	313.00		12100	11500	36374	244.40	236.95	196.00	163048	165120		
	600			454.32	73664	424.30	108950	312.17	109000	313.00		12140	12140	34927	244.40	235.95	195.00	162189	165120		
	700	506.63	65384	454.22	72975	424.15	107320	311.97	107000	313.00		12140	12140	34856	244.40	237.05	196.00	160456	162065		
	800			454.12	72287	424.10	106235	311.84	106000	313.00		12140	12140	34750	244.20	237.25	196.00	159484	159060		
	900			454.03	71598	423.95	105420	311.74	105000	313.00		12140	12140	34679	244.30	237.80	196.00	158380	151765		
	1000			453.94	70909	423.85	104880	311.68	105000	313.00		1214(	12140	34432	244.20	238.00	196.00	156337	158705		

TABLE A.1e

GRAND FALLS TO BEECHWOOD CHRONOLOGY

BEECHWOOD NBEPC				OBSERVED JAM LOCATION			
POND EL. (Measured in ft)	TAILRACE EL. (Measured in ft)	INFLOW (Calc. 4 in ft^3/s)	OUTFLOW (Calc. 3 in ft^3/s)	JAM POSITION	HEAD	TAIL	TIME	COMMENTS
							743	
							756	
202.00	224520	229615					800	
							830	
							840	
202.00	224215	227320					900	
							915	
202.00	223218	226850					1000	
							1015	
							1030	
202.00	221475	226850					1100	
							1110	
202.00	218733	223620					1200	
							1233	
202.00	218005	220755					1300	
							1330	
							1345	
202.00	217594	219635					1400	
							1450	
202.00	216630	219635					1500	
201.50	216073	217190					1600	
201.50	216118	214800					1700	
201.50	215687	214800					1800	
200.50	215258	212865					1900	
							1905	
							1920	
200.50	213734	213880					2000	
							2030	
200.50	214298	213880					2100	
200.50	213922	214200					2200	
200.50	212810	214200					2300	
200.50	211571	214700					2400	
200.50	210219	211815					100	
200.00	209255	212920					200	
200.00	207053	210745					300	
200.00	205844	210745					400	
200.00	202457	208745					500	
							550	
200.00	199864	206440					600	
199.50	197690	203620					700	
							710	
199.00	196198	201490					800	
199.00	194074	201490					900	
							928	
199.00	192117	200500					1000	
199.00	190981	198590					1100	
198.50	190095	190960					1200	
198.50	189004	192690					1300	
198.20	187237	189425					1400	
198.00	186018	188145					1500	
198.00	185125	189400					1600	
							1626	
198.00	183462	189700					1700	
198.00	180138	189400					1800	
198.00	175217	186745					1900	
198.00	177563	182965					2000	
198.00	179528	178685					2100	
197.50	174784	174250					2200	
196.50	171424	172280					2300	
196.50	170141	172290					2400	
196.50	168360	173000					100	
	166682	167745					200	
196.50	165344						300	
196.50	163951	166825					400	
196.00	163048	165120					500	
195.00	162189	165120					600	
196.00	160456	162065					700	
196.00	159484	159060					800	
196.00	158380	151765					900	
196.00	156337	158705					1000	

DATE	TIME	FORT KENT NBEPC ELEVATION (Measured in ft)	FORT KENT NBEPC DISCHARGE (Calc. 1 in ft³/s)	EDMUNDSTON WSC-01AD004 ELEVATION (Measured in ft*)	EDMUNDSTON WSC-01AD004 DISCHARGE (Calc. 1 in ft³/s*)	EDMUNDSTON WSC-01AD004 HEADPOND (Meas
	1100			453.85	70451	423.80
	1200			453.76	69762	423.70
	1300			453.67	69073	423.60
	1400			453.57	68385	423.50
	1500	505.80	59469	453.49	67899	423.40
	1600			453.41	67896	423.40
	1700			453.33	67893	423.25
	1800			453.25	67888	423.20
	1900			453.17	65730	423.00
	2000			453.09	65042	423.00
	2100			453.01	64582	422.90
	2200			452.93	64123	422.85
	2300	505.21	55439	452.87	63684	422.75
	2400			452.82	63291	422.70

* Converted from metric to imperial units using
1 m ^{3}/s = 35.315 cfs
1 m =3.2808 ft

** Grand Falls T.R. El. is the same as the WSC gauge level.

calc.1 - calculated using a stage-discharge relationship
calc.2 - calculated by backrouting outflow discharge taking accou
calc.3 - calculated as plant discharge plus spill discharge
calc.4 - calculated using the SOCH routing model -- calculated ig

note - all elevations are referred to Geodetic Survey of Canada D
(except Fort Kent which refers to United States Geodetic D
- italic comments are inferences from the data. All other com

TABLE A.1f

GRAND FALLS TO BEECHWOOD CHRONOLOGY

TIME	FORT KENT NBEPC ELEVATION (Measured in ft)	FORT KENT NBEPC DISCHARGE (Calc. 1 in ft³/s)	EDMUNDSTON WSC-01AD004 ELEVATION (Measured in ft*)	EDMUNDSTON WSC-01AD004 DISCHARGE (Calc. 1 in ft³/s*)	GRAND FALLS NBEPC HEADPOND EL. (Measured in ft)	GRAND FALLS NBEPC INFLOW (Calc. 2 in ft³/s)	GRAND FALLS WSC-01AF002 ELEVATION** (Measured in ft*)	GRAND FALLS WSC-01AF002 OUTFLOW (Calc.1 in ft³/s)	TOBIQUE RIVER NBEPC HEADPOND EL. (Measured in ft)	TOBIQUE RIVER NBEPC TAILRACE EL. (Measured in ft)	TOBIQUE RIVER NBEPC INFLOW (Calc.2 in ft³/s)	TOBIQUE RIVER NBEPC OUTFLOW (Calc.3 in ft³/s)	AROOSTOOK RIVER WSC 0AG003 OUTFLOW (Calc. 1 in ft³/s*)	PERTH-NBEPC ELEVATION (Measured in ft)	BEECHWOOD NBEPC HEADPOND EL. (Measured in ft)	BEECHWOOD NBEPC TAILRACE EL. (Measured in ft)	BEECHWOOD NBEPC INFLOW (Calc.4 in ft³/s)	BEECHWOOD NBEPC OUTFLOW (Calc.3 in ft³/s)	JAM POSITION	OBSERVED JAM LOCATION HEAD	OBSERVED JAM LOCATION TAIL	OBSERVED JAM LOCATION TIME	COMMENTS
1100			453.85	70451	423.80	103480	311.51	104000	313.00		12140	12140	34044	244.20	238.10	196.00	156076	158875				1100	
1200			453.76	69762	423.70	102640	311.41	103000	313.00		12140	12140	33231	244.30	238.20	196.00	154771	159450				1200	
1300			453.67	69073	423.60	102080	311.35	102000	312.95		11540	12140	32596	244.30	238.20	196.50	153236	158950				1300	
1400			453.57	68385	423.50	100965	311.22	101000	312.95		12140	12140	32313	244.20	238.30	196.50	151735	155400				1400	
1500	505.80	59469	453.49	67899	423.40	110125	311.12	100000	312.95		12140	12140	32349	244.10	238.30	196.50	150527	155400				1500	
1600			453.41	67896	423.40	99005	310.99	99000	312.75		9470	12140	32137	244.10	238.30	196.50	149525	153020				1600	
1700			453.33	67893	423.25	97605	310.82	98000	312.65		9940	12140	31889	244.00	238.30	196.50	148366	153020				1700	
1800			453.25	67888	423.20	96765	310.76	97000	312.75		12160	10960	31678	243.80	238.20	196.50	146389	152440				1800	
1900			453.17	65730	423.00	95925	310.63	96000	312.85		12160	10960	31113	243.80	238.20	196.50	144459	149795				1900	
2000			453.09	65042	423.00	95085	310.53	95000	312.85		10960	10960	30653	243.70	238.30	196.50	143033	147130				2000	
2100			453.01	64582	422.90	94245	310.43	94000	312.90		11560	10960	30371	243.60	238.40	196.00	141644	145225				2100	
2200			452.93	64123	422.85	93685	310.36	93000	312.95		11560	10960	30194	243.50	238.40	196.00	140521	142170				2200	
2300	505.21	55439	452.87	63684	422.75	93125	310.33	93000	312.95		11500	11500	29982	243.50	238.60	196.00	139992	139935				2300	
2400			452.82	63291	422.70	91725	310.13	92000	312.95		11500	11500	28358	243.90	238.80	196.00		137855				2400	

ted from metric to imperial units using
s = 35.315 cfs
.2808 ft

Falls T.R. El. is the same as the WSC gauge level.

calculated using a stage-discharge relationship
calculated by backrouting outflow discharge taking account of storage changes
calculated as plant discharge plus spill discharge
calculated using the SOCH routing model -- calculated ignoring effects of jam storage and release mechanisms

ll elevations are referred to Geodetic Survey of Canada Datum
except Fort Kent which refers to United States Geodetic Datum)
talic comments are inferences from the data. All other comments are actual observations.

DATE	TIME	BEECHWOOD NBEPC: TAILRACE EL. (Measured in ft)	BEECHWOOD NBEPC: INFLOW (Calc. 4 in ft³/s)	BEECHWOOD NBEPC: OUTFLOW (Calc. 3 in ft³/s)	BEECHWOOD NBEPC: ELEVATION (Measured in ft*)		FLORENCEVILLE WSC - 01AJ001: DISCHARGE (Calc. 1 in ft³/s*)	BIG PRESQUE ISLE STREAM WSC 01AJ004: DISCHARGE (Calc. 1 in ft³/s*)	SIMONDS - WSC 01AJ009: ELEVATION (Measured in ft*)	BECAGUIMEC STREAM WSC 01AJ010: DISCHARGE (Calc. 1 in ft³/s*)	COLD STREAM WSC 01AJ011: DISCHARGE (Calc. 1 in ft³/s*)	HARTLAND WSC 01AJ008: ELEVATION (Measured in ft*)	GRAFTON - NBEPC: ELEVATION (Measured in ft*)	WOODSTOCK - NBEPC: ELEVATION (Measured in ft)	NBEPC: ELEVATION (Measured in ft)	MEDUXNEKEAG RIVER: WSC 01AJ003: DISCHARGE (Calc. 1 in ft³/s*)	MEDUXNEKEAG RIVER: EEL - WSC 01AK008: DISCHARGE (Calc. 1 in ft³/s*)	SHOGOMOC STREAM: WSC 01AK001 - DISCHARGE (Calc. 1 in ft³/s*)	NAKAWICK RIVER WSC 01AK007 DISCHARGE (Calc. 1 in ft³/s*)	MACTAQUAC NBEPC: HEADPOND EL. (Measured in ft)	MACTAQUAC NBEPC: TAILRACE EL. (Measured in ft)	MACTAQUAC NBEPC: INFLOW (Calc. 4 in ft³/s)	MACTAQUAC NBEPC: OUTFLOW (Calc. 3 in ft³/s)	FREDERICTON - NBEPC: ELEVATION (Measured in ft*)	MAUGERVILLE - NBEPC: ELEVATION (Measured in ft*)	JAM POSITION	HE
27-Mar-87 to 29-Mar-87	1800						886		922	353																	
30-Mar-87	100	188.50	35215	29500	177.99		985	147.59	1010	420	141.64	131.32	130.95	131.08	2952	1363	417	918	131.04	17.13							
	200	188.50	27069	29500	177.99		1003	147.65	1010	417	141.72	131.43	131.11	131.23	2966	1374	424	908									
	300	188.50	25770	29500	177.98		1021	147.70	1014	413	141.80	131.66	131.22	131.37	2836	1384	431	901	131.30	15.85		22800					
	400	188.50	29745	29500	177.98		1017	147.72	1014	410	141.88	131.74	131.26	131.41	2822	1395	427	890									
	500	188.50	35738	29700	177.97		1014	147.72	1014	403	141.91	131.78	131.30	131.45	2995	1406	424	886									
	600	188.50	38433	29701	177.96		1014	147.69	1017	399	141.85	131.82	131.35	131.50	2998	1413	420	886									
	700	188.50	38053	29800	177.95		1010	147.72	1024	392	141.86	131.88	131.44	131.62	2998	1416	417	883	131.50	18.02							
	800	188.50	37848	29800	177.90		1010	147.75	1028	388	141.88	131.98	131.46	131.64	2977	1420	417	879									
	830																										
	900	188.50	37398	32100	177.89	I	1017	147.78	1056	388	141.90	131.98	131.34	131.47	3037	1508	417	890									
	1000	188.50	37457	31515	178.00	C	1021	147.81	989	385	141.92	131.88	131.27	131.39	3094	1413	417	904									
	1100	188.50	38538	34040	178.05	E	1077	147.84	1021	381	141.98	131.76	131.18	131.33	3115	1391	417	939	131.20	20.75		60450					
	1200	189.00	38663	34970	178.12		1077	147.90	989	378	142.01	131.68	131.12	131.26	3171	1402	417	932									
	1300	189.00	38984	34980	178.13	E	1038	147.99	1187	381	142.03	131.62	130.98	131.13	3323	1420	417	996							2	< Trans Canad	
	1400	189.00	39452	36650	178.17	F	1197	148.10	1031	385	142.11	131.48	130.91	131.03	3814	1430	424	1045								Highway Br	
	1500	189.00	39891	36660	177.68	F	1211	148.21	1568	403	142.27	131.43	130.89	131.03	3411	1427	427	1070								Florencevil	
	1600	189.00	41247	37430	178.24	E	1324	148.32	1547	417	142.47	131.43	130.86	131.00	3426	1420	441	1098	130.95	20.68							
						C																					
						T																					
						O																					
	1630					N																					
	1700	189.00	42684	37430	178.38		1271	148.36	1427	456	142.65	131.40	130.83	130.98	3510	1444	452	1127									
	1800	189.00	43064	39600	178.41	G	1349	148.42	1497	498	142.72	131.39	130.75	130.87	3486	1391	456	1144									
	1900	189.00	44069	41160	178.36	A	1716	148.51	1586	540	142.80	131.28	130.68	130.85	3532	1480	459	1240	130.53	21.76		69900					
	2000	189.00	47090	41160	176.46	U	1515	148.67	1536	576	142.90	131.17	130.58	130.81	3708	1497	463	1197									
	2100	189.00	49281	43080	175.34	G	1540	149.01	1487	614	143.11	131.09	130.47	130.63	3885	1515	470	1176									
	2140				175.46	E																					
	2200	189.50	49982	43105	175.58		1564	149.18	1444	650	143.34	130.98	130.40	130.55	3991	1416	473	1180							3.1	< Buckwheat	
	2300	189.50	50386	44845	175.68		1593	149.19	1434	671	143.43	130.95	130.35	130.46	4450	1543	480	1183	130.16	21.78							
	2400	189.50	50777	44995	175.80		1628	148.82	1409	689	143.34	130.88	130.33	130.44	4273	1529	484	1201									
31-Mar-87	100	189.50	51095	44995	175.92		1670	148.88	1434	706	143.12	130.88	130.23	130.37	4308	1515	491	1201									
	200	189.50	51341	44995	175.98		1709	149.26	1459	706	143.33	130.73	130.20	130.31	5509	1564	494	1243				58500					
	300	189.50	51469	44995	175.96		1748	149.25	1519	706	143.43	130.73	130.32	130.37	4662	1603	501	1300	130.20	19.05							
	400	189.50	51454	45000	175.93		1798	149.50	1543	696	143.65	130.87	130.40	130.46	4344	1656	505	1211	130.15	20.15		57450					
	500	189.50	51660	46600	175.79		1773	149.72	1561	682	143.87	130.97	130.47	130.60	4450	1628	516	1194	130.15	20.27		56700					
	600	189.50	51885	46700	176.05		1790	149.85	1586	667	144.03	131.02	130.49	130.60	4520	1628	540	1194	130.15	20.75		60000					
	700	190.00	52210	48250	175.96		1812	149.85	1607	657	144.04	131.03	130.49	130.61	7875	1610	547	1194	130.10	21.80		77700					
	800	190.50	52797	49330	176.84		1829	149.86	1621	650	144.05	131.03	130.48	130.61	4520	1642	554	1194	130.05	22.10		79200					
	815																										
	853																										
	900	190.50	52637	50900	177.24		1847	149.64	1635	643	143.91	130.98	130.40	130.50	4697	1681	562	1211	130.00	22.19		77100					
	1000	191.00	53351	52300	177.53		1865	149.45	1681	632	143.70	130.90	130.28	130.37	4768	1692	569	1190	130.00	21.85		74100					
	1100	191.00	55176	52300	176.49		1879	149.57	1723	625	143.97	130.82	130.21	130.31	4768	1759	572	1183	130.00	21.20		69000					
	1200	191.00	57094	53875	177.76		1900	149.55	1723	618	143.82	130.74	130.23	130.31	4803	1699	576	1208	129.90	21.97		74100					
	1300	191.50	62273	52700	178.38		1921	149.56	1723	614	143.45	130.78	130.27	130.36	4768	1737	576	1225	129.75	22.37		83544					
	1330																										
	1400	191.50	59274	60865	178.65		1974	150.12	1723	622	143.70	130.72	130.13	130.23	4732	1646	579	1232	129.85	22.19		82800					
	1500	192.00	59313	64345	179.01														129.70	22.83		78670					
	1545						2031	150.97	1723	625	144.06	130.64	129.98	130.16	4803	1875	583	1285									
	1600	192.50	60384	68000	179.09		2094	154.21	1727	639	144.49	130.54	130.08	130.18	6251	1858	597	1384	129.57	23.59		100670					
	1640																										
	1700	193.00	63174	70340	173.68	88994	2182	156.90	1734	664	149.86	130.63	130.11	130.13	5474	1790	618	1437	129.32	24.17		105784					
	1750																										
	1800	192.50	66630	70340	172.96	79106	2260	159.28	1745	692	154.99	130.80	130.28	130.43	5439	1865	636	1508	129.22	24.34		111556					
	1840																										
	1900	192.50	68235	70270	172.60	74515	2165	160.89	1752	735	154.92	130.80	129.98	130.06	5898	1964	657	1586	129.00	24.92		124418			6	< Sproule's	
	1920																										
	2000	192.50	70668	70340	172.53	73808	2313	161.47	1790	773	155.57	130.44	129.75	129.93	5933	2009	678	1667	128.94	25.00		120271					
	2015																										
	2100	192.50	72803	72500	172.58	74515	2391	161.59	1836	816	156.05	130.25	129.68	129.68	5756	2006	692	1734	128.83	25.00		115313					
	2135																										
	2200	193.00	75529	74490	172.72	76280	2423	161.54	1886	848	156.67	130.30	129.75	129.82	5827	2020	706	1720	128.70	25.00		121508					
	2205																										

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TABLE A.2a

BEECHWOOD TO MACTAQUAC CHRONOLOGY

OUTFLOW (Calc. 3 in ft^3/s)	FREDERICTON-NBEPC ELEVATION (Measured in ft*)	MAUGERVILLE-NBEPC ELEVATION (Measured in ft*)	OBSERVED JAM LOCATION: JAM POSITION	OBSERVED JAM LOCATION: HEAD	OBSERVED JAM LOCATION: TAIL	TIME	COMMENTS
							< Ice at Bath and very black. Little breakup Bath to Buckwheat Bridge, then a few open spots to
						1800	Hartland, then solid ice downstream.
						100	
22800						200	
						300	
						400	
						500	
						600	
						700	
						800	
						830	< Beechwood started spilling.
						900	
						1000	
60450						1100	
						1200	
			2	< Trans Canada Highway Bridge at Florenceville	< Green Island	1300	< Open water from below Trans Canada Highway bridge
						1400	to below Florenceville covered bridge.
						1500	< Black ice to Buckwheat Bridge where there is a
						1600	small open channel below and at Stickney. Ice has run at Big Presque Isle Stream and Becaguimec Stream. Channel open from Becaguimec Stream to Sproules Island, then ice covered to Mactaquac. Meduxnekeag ice has run. (into 'interval')
						1630	< Jam started to move from position 2.
						1700	
						1800	
69900						1900	
						2000	
						2100	
						2140	
			3.1	< Buckwheat Bridge	< Just above Florenceville covered bridge	2200	< 3.3 km long jam. Small run of ice Stickney to
						2300	Simonds.
						2400	
						100	
58500						200	
						300	
57450						400	
56700						500	
60000						600	< Open from Beechwood to 3 km above Buckwheat
77700						700	Bridge, then 3 km of jam, then open river for
79200						800	next 5 km through Stickney and Simonds. Small jam
						815	1 km above Simonds gauge at Peel Isl. ~ 1 km long -no problem. No change Hartland to Mactaquac.
						853	< Buckwheat Bridge unchanged. 5 km of broken
77100						900	stationary ice above Hartland then 5 km open.
74100						1000	
69000						1100	
74100						1200	
83544						1300	< Ice started to move at Buckwheat Bridge. Little change downstream.
						1330	
82800						1400	
78670						1500	
						1545	< Ice moving in Simonds area.
00670						1600	
						1640	< Ice moving through Hartland area. Sudden elevation
05784						1700	drop at East Florenceville. I(Gauge now ice free)
						1750	*(Gauge now ice free)*
11556						1800	
			6	< Sproule's Island	< Simonds	1840	< Water reached road in Simonds. Below covered
24418						1900	bridge in Hartland.
						1920	< Water over road in Simonds.
20271						2000	
						2015	< Road closed in Simonds.
15313						2100	
						2135	< Ice started moving at Hartland covered bridge.
21508						2200	*(Hartland level dropped and Simonds level did not implies jam also held between locations (Upper Becaguimec Island)*
						2205	< Ice had run through Hartland (level dropping).

DATE	TIME	TAILRACE EL. (Measured in ft)	BEECHWOOD NBEPC INFLOW (Calc. 4 in ft³/s)	BEECHWOOD NBEPC OUTFLOW (Calc. 3 in ft³/s)	BEECHWOOD NBEPC ELEVATION (Measured in ft*)	FLORENCEVILLE WSC - 01AJ001 DISCHARGE (Calc. 1 in ft³/s*)	BIG PRESQUE ISLE STREAM WSC 01AJ004 DISCHARGE (Calc. 1 in ft³/s)	SIMONDS - WSC 01AJ009 ELEVATION (Measured in ft*)	BECAGUIMEC STREAM WSC 01AJ010 DISCHARGE (Calc. 1 in ft³/s*)	COLD STREAM WSC 01AJ011 DISCHARGE (Calc. 1 in ft³/s*)	HARTLAND WSC 01AJ008 ELEVATION (Measured in ft*)	GRAC
	2300	193.00	76622	70000	172.93	79106	2514	161.22	1942	869	154.33	130
	2400	193.00	78343	75860	173.00	79812	2606	161.44	2009	897	155.91	129
01-Apr-87	5											
	15					80518						
	30											
	45											
	50											
	100	194.50	79673	90700	173.20	82637	2680	161.55	2045	932	156.45	129
	115											
	120											
	130											
	145											
	200	194.00	79861	96200	173.76	90053	2769	159.87	2133	971	150.52	130
	215											
	230											
	245											
	300	194.50	79786	95200	174.10	94644	2861	156.83	2161	1014	152.21	130
	310											
	315											
	320											
	330											
	345										148.65	
	400	194.50	82899	94500	174.04	93938	2952	153.85	2257	1031	148.19	132
	415											
	430											
	445										149.01	
	500	194.00	87008	90200	173.84	91113	3048	152.62	2348	1067	149.23	130
	515											
	530											
	545											
	600	194.00	88099	93000	173.82	90760	3143	152.64	2433	1102	149.56	130
	615											
	630											
	645											
	700	196.00	89610	110200	174.27	97116	3235	152.65	2500	1119	149.16	130
	715											
	730											
	800	196.25	97660	112000	175.23	110889	3330	152.61	2571	1155	149.78	130
	815											
	830											
	845											
	900	196.00	99565	113000	175.39	113361	3348	153.58	2716	1187	150.60	130
	915											
	930											
	945											
	1000	197.50	98956	121600	175.58	116186	3637	154.39	2861	1208	151.41	130
	1015											
	1030											
	1045											
	1050											
	1100	197.50	107940	139200	176.54	131019	3708	154.98	2970	1236	152.22	130
	1115											
	1130											
	1200	198.00	114339	140100	177.12	140201	3814	155.16	2952	1268	149.95	134
	1215											
	1230											
	1245											
	1300	198.00	119709	138370	177.45	145498	3885	154.29	2938	1303	148.26	137
	1315											
	1330											
	1345											
	1400	198.00	121020	135700	177.37	144085	3955	154.27	2949	1321	148.52	141
	1415											
	1430											

TABLE A.2b

BEECHWOOD TO MACTAQUAC CHRONOLOGY

...US - WSC 01AJ009 ELEVATION (Measured in ft)	BECAGUIMEC STREAM WSC 01AJ010 DISCHARGE (Calc. 1 in ft³/s)	COLD STREAM WSC 01AJ011 DISCHARGE (Calc. 1 in ft³/s)	HARTLAND WSC 01AJ008 ELEVATION (Measured in ft)	GRAFTON - NBEPC ELEVATION (Measured in ft)	WOODSTOCK - NBEPC ELEVATION (Measured in ft)	NBEPC ELEVATION (Measured in ft)	MEDUXNEKEAG RIVER (at mouth) ELEVATION (Measured in ft	MEDUXNEKEAG RIVER WSC 01AJ003 DISCHARGE (Calc. 1 in ft³/s)	EEL - WSC 01AK008 DISCHARGE (Calc. 1 in ft³/s)	SHOGOMOC STREAM WSC 01AK001 DISCHARGE (Calc. 1 in ft³/s)	NAKAWICK RIVER WSC 01AK007 DISCHARGE (Calc. 1 in ft³/s)	MACTAQUAC NBEPC HEADPOND EL. (Measured in ft)	MACTAQUAC NBEPC TAILRACE EL. (Measured in ft)	MACTAQUAC NBEPC INFLOW (Calc. 4 in ft³/s)	MACTAQUAC NBEPC OUTFLOW (Calc. 3 in ft³/s)	FREDERICTON - NBEPC ELEVATION (Measured in ft)	MAUGERVILLE - NBEPC ELEVATION (Measured in ft)	OBSERVED JAM LOCATION JAM POSITION	OBSERVED JAM LOCATION HEAD	OBSERVED JAM LOCATION TAIL	TIME	COMMENTS
22	1942	869	154.33	130.50	129.48	129.53	6004	2437	720	1914	128.50	25.11		118058							2300	
44	2009	897	155.91	129.92	129.33	129.38	6180	2341	731	2048	128.50	25.30	104997	121658							2400	
																					5	
																					15	
																					30	< Jam below Hartland.
																					45	
55	2045	932	156.45	129.92	129.35	129.39	6266	2384	745	1971	128.10	25.15	107017	115060							50	< Water on road at Pole Hill Road intersection.
																					100	
																					115	
																					120	< Ice let go at Hartland (Woodstock gauge jumped up).
																					130	
37	2133	971	150.52	130.00	130.08	130.13	6463	2430	763	2048	128.10	25.50	109779	126192			6.1	< Pine Island			145	
																					200	< Jam at Pine Island. Sheet ice at Woodstock.
																					215	
03	2161	1014	152.21	130.60	130.53	130.53	6639	2433	777	2165	128.00	25.87	113178	133430							230	
																					245	
																					300	< *(Jam below Simonds released and went through Hartland)*
					131.45																310	
																					315	
																					320	
			148.65																		330	
35	2257	1031	148.19	132.25	130.38	130.53	6851	2232	791	2221	127.80	26.08	113912	138598							345	< Sheet ice below Woodstock
																					400	
																					415	
			149.01																		430	
32	2348	1067	149.23	130.80	129.91	130.00	7063	1981	819	2204	128.40	26.30	116737	140574				< 1 km below Pine Island			445	
																					500	
																					515	
																					530	
34	2433	1102	149.56	130.50	129.82	129.85	7275	1794	848	2271	128.00	26.54	123077	142596							545	
																					600	
																	6.2	< railroad bridge at Indian Island	< Ackers Creek		615	< Main channel blocked - broken ice extends just past railroad bridge piers, secondary channel open.
																					630	< Railroad track covered. 2 ft on road at Newburg
25	2500	1119	149.16	130.40	130.25	130.13	7487	2024	876	2338	127.90	27.45	132378	154620	18.18	14.30					645	Junction. Little change down to Mactaquac.
																					700	
																					715	
31	2571	1155	149.78	130.70	129.73	129.83	7734	2066	901	2440	127.80	27.40	144219	167109	18.31	14.57					730	
																					800	
																					815	
8	2716	1187	150.60	130.32	129.53	129.61	7946	2935	922	2885	127.60	27.29	150157	150996	18.70	15.29					830	
																					845	
																					900	
																					915	
9	2861	1208	151.41	130.20	129.56	129.63	8193	2186	943	2726	127.30	27.46	152211	152888	18.96	15.12					930	
																					945	
																					1000	
																					1015	
																					1030	
																					1045	< Photos show high velocity and large headloss in open secondary channel.
8	2970	1236	152.22	130.35	130.55	129.83	8440	2228	946	2656	127.20	27.62	154914	163838	19.23	15.32					1050	< Photos show tail still at Ackers Creek.
																					1100	< Ice started to move into Woodstock area.
																					1115	< Indian Island railroad bridge failed.
																					1130	
6	2952	1268	149.95	134.00	134.53	129.83	8687	2271	975	2733	127.10	27.05	166949	160340	19.48	15.42	8	< Woodstock Pumping Station	< Just above Indian Island railroad bridge		1200	< Ice at Grafton jamming badly. Photos show 2 spans of railroad bridge gone. Ice had run at Pine Island and Newburg Junction. Tail of moving ice pack just above railroad bridge.
																					1215	
																					1230	
9	2938	1303	148.26	137.00	138.28	134.63	8970	2313	1010	2811	127.15	27.77	181564	161840	19.62	15.78					1245	
																					1300	
																					1315	
																	8.1	< Cozy Cabins (0.5 mile below Pumping Station)	< Woodstock		1330	< Meduxnekeag River ice has not run from "interval",
7	2949	1321	148.52	141.40	137.33	136.63	9217	2356	1045	2885	127.20	27.20	181689	163060	19.75	15.85					1345	open above. Ice still moving in Woodstock.
																					1400	
																					1415	
																					1430	

DATE	TIME	TAILRACE EL. (Measured in ft)	BEECHWOOD NBEPC INFLOW (Calc. 4 in ft^3/s)	BEECHWOOD NBEPC OUTFLOW (Calc. 3 in ft^3/s)	BEECHWOOD NBEPC ELEVATION (Measured in ft*)	FLORENCEVILLE WSC - 01AJ001 DISCHARGE (Calc. 1 in ft^3/s*)	BIG PRESQUE ISLE STREAM WSC 01AJ004 DISCHARGE (Calc. 1 in ft^3/s*)	SIMONDS - WSC 01AJ009 ELEVATION (Measured in ft*)	BECAGUIMEC STREAM WSC 01AJ010 DISCHARGE (Calc. 1 in ft^3/s*)	COLD STREAM WSC 01AJ011 DISCHARGE (Calc. 1 in ft^3/s*)	HARTLAND WSC 01AJ008 ELEVATION (Measured in ft*)	GRAFTON - NBEPC ELEVATION (Measured in ft*)	WOODSTOCK - NBEPC ELEVATION (Measured in ft)	NBEPC ELEVATION (Measured in ft)	MEDUXNEKEAG RIVER WSC 01AJ003 DISCHARGE (Calc. 1 in ft^3/s*)	MEDUXNEKEAG RIVER EEL - WSC 01AK008 DISCHARGE (Calc. 1 in ft^3/s*)	SHOGOMOC STREAM WSC 01AK001 DISCHARGE (Calc. 1 in ft^3/s*)	NAKAWICK RIVER WSC 01AK007 DISCHARGE (Calc. 1 in ft^3/s*)	MACTAQUAC NBEPC HEADPOND EL. (Measured in ft)	MACTAQUAC NBEPC TAILRACE EL. (Measured in ft)	MACTAQUAC NBEPC INFLOW (Calc. 4 in ft^3/s)	MACTAQUAC NBEPC OUTFLOW (Calc. 3 in ft^3/s)	FREDERICTON - NBEPC ELEVATION (Measured in ft*)	MAUGERVILLE - NBEPC ELEVATION (Measured in ft*)	JAM POSITION	
	1445																										
	1500	198.00	122608	131600	177.07	139494	4167	154.04	2988	1321	148.10		137.53	137.18	9500	2398	1081	2963	127.40	27.40	182892	161976	19.8	16.14			
	1515																										
	1530																										< 0.5 mi
	1545																										Cozy C
	1600	198.00	125465	129300	176.89	136669	4132	153.50	3002	1342	147.72		137.43	137.08	9712	2440	1116	3041	127.38	27.03	187151	170549	19.9	16.40			
	1615																										
	1630																										
	1645																										
	1700	197.50	127621	131100	176.98	138082	4202	153.19	3048	1356	147.29		137.18	136.83	9924	2483	1151	3104	127.77	26.87	193141	164799	20.0	16.57			
	1715																										
	1730																										
	1745																										
	1800	197.50	134045	133500	177.26	142319	4273	153.04	3111	1384	147.11		136.78	136.33	10171	2525	1187	3132	127.92	26.79	197977	163707	20.1	16.90			
	1815																				197977						
	1830																										
	1845																										
	1900	198.50	161407	139200	177.64	148676	4344	153.08	3147	1363	147.04		137.[illegible]	136.68	10383	2567	1215	3157	127.93	26.93	200471	156807	20.1	16.83			
	1915																										
	1930																										
	1945																										
	2000	199.00	170095	148400	177.98	154327	4414	153.29	3171	1346	147.26		137.15	136.78	10700	2606	1247	3185	128.09	26.89	200838	164841	20.1	17.06			
	2015																										
	2030																										
	2045																										
	2100	199.00	166489	149100	178.26	159271	4414	153.61	3196	1360	147.56		137.21	136.81	10948	2642	1278	3214	128.08	27.42	202772	172670	20.2	17.59			
	2115																										
	2130																										
	2145																										
	2200	199.00	171447	148300	178.45	162449	4450	153.93	3224	1338	147.86		137.35	136.96	11160	2677	1307	3242	128.08	27.85	205858	188766	20.31	17.65			
	2215																										
	2230																										
	2245																										
	2300	199.00	180108	147900	178.45	162096	4450	154.15	3256	1314	148.16		137.55	137.18	11371	2712	1335	3270	128.10	27.90	210450	190413	20.37	17.62			
	2315																										
	2330																										
	2345																										
	2400	200.00	188882	164200	178.75	167393	4450	154.23	3288	1289	148.22		137.78	137.43	11619	2751	1356	3295	128.05	28.48	214599	203061	20.51	17.95			
02-Apr-87	15																										
	30																										
	45																										
	100	200.00	195208	164200	179.41	179047	4485	154.60	3309	1268	148.49		137.91	137.58	11725	2786	1374	3313	127.90	29.00	221387	217536	20.70	18.04			
	115																										
	130																										
	145																										
	200	200.50	201186	176400	179.96	188582	4520	155.02	3323	1247	148.95		138.05	137.73	11866	2822	1395	3313	127.85	29.50	231153	225003	20.90	18.21			
	215																										
	230																										
	245																										
	300	201.50	208799	188000	180.50	198470	4556	155.43	3344	1250	149.50		138.21	136.63	11972	2857	1409	3281	127.65	29.93	234452	235098	21.10	18.47			
	315																										
	330																										
	345																										
	400	201.50	214537	189300	181.04	208712	4626	155.83	3362	1293	150.06		138.38	138.23	12042	2892	1420	3253	127.43	30.24	234979	247070	21.44	18.67			
	415																										
	430																										
	445																										
	500	202.00	219347	195450	181.43	216128	4556	156.22	3376	1282	150.55		138.78	138.78	12113	2928	1430	3221	127.25	30.50	240218	250493	21.8	18.90			
	515																										
	530																										
	545																										
	600	201.50	219095	184725	181.51	217540	4556	156.52	3383	1275	151.02		139.31	139.13	12184	2963	1441	3178	127.10	30.87	249145	255317	22.1	19.16			
	605																										
	615																										< 4 km d
	620																										of tai
	630																										
	645																										
	655																										

TABLE A.2c

BEECHWOOD TO MACTAQUAC CHRONOLOGY

CTAQUAC NBEPC (Calc.4 in ft³/s)	OUTFLOW (Calc.3 in ft³/s)	FREDERICTON-NBEPC ELEVATION (Measured in ft*)	MAUGERVILLE-NBEPC ELEVATION (Measured in ft*)	OBSERVED JAM LOCATION: JAM POSITION	OBSERVED JAM LOCATION: HEAD	OBSERVED JAM LOCATION: TAIL	TIME	COMMENTS
							1445	< Photo shows ice still held in main channel at Indian Island railroad bridge.(open water downstream)
2	161976	19.86	16.14				1500	Relief channel open.
							1515	
				< 0.5 mile below Cozy Cabins			1530	< Ice moved to 0.5 mile below Cozy Cabins at Lower Woodstock.
1	170549	19.9	16.40				1545	
							1600	
							1615	
							1630	< Ice reported packing on Grafton side of river.
							1645	< Photos show open lead below head of jam on Grafton side.
1	164799	20.0	16.57				1700	
							1715	
							1730	
							1745	
7	163707	20.1	16.90				1800	< Photos show moving ice in Woodstock (~ 20% coverage).
								Photos show open lead at Gibson Millstream.
							1815	
							1830	
							1845	
1	156807	20.1	16.83				1900	
							1915	
							1930	
							1945	
8	164841	20.1	17.06				2000	
							2015	
							2030	
							2045	
2	172670	20.2	17.59				2100	
							2115	
							2130	
							2145	
8	188766	20.31	17.65				2200	
							2215	
							2230	
							2245	
0	190413	20.37	17.62				2300	
							2315	
							2330	
							2345	
9	203061	20.51	17.95				2400	
							15	
							30	< Heavy drawdown started at Beechwood - 8 of 9 gates raised from 6 ft to 12 ft opening.
							45	
7	217536	20.70	18.04				100	
							115	
							130	
							145	
3	225003	20.9	18.21				200	< Beechwood gates raised to 14 ft.
							215	
							230	
							245	
2	235098	21.1	18.47				300	
							315	
							330	
							345	
9	247070	21.4	18.67				400	
							415	
							430	
							445	
8	250493	21.8	18.90				500	
							515	
							530	
							545	
5	255317	22.1	19.16				600	
				< 4 km downstream of tail	< Across junction at Parkers Road		605	
							615	
							620	
							630	
							645	
							655	

DATE	TIME	TAILRACE EL. (Measured in ft)	BEECHWOOD NBEPC: INFLOW (Calc.4 in ft³/s)	BEECHWOOD NBEPC: OUTFLOW (Calc.3 in ft³/s)	BEECHWOOD NBEPC: ELEVATION (Measured in ft*)	FLORENCEVILLE WSC - 01AJ001: DISCHARGE (Calc.1 in ft³/s*)	BIG PRESQUE ISLE STREAM WSC 01AJ004: DISCHARGE (Calc.1 in ft³/s*)	SIMONDS - WSC 01AJ009: ELEVATION (Measured in ft*)	BECAGUIMEC STREAM WSC 01AJ010: DISCHARGE (Calc.1 in ft³/s*)	COLD STREAM WSC 01AJ011: DISCHARGE (Calc.1 in ft³/s*)	HARTLAND WSC 01AJ008: ELEVATION (Measured in ft*)	GRAF
	700	200.00	217784	177250	180.97	207299	4520	156.73	3394	1282	151.26	
	715											
	730											
	745											
	800	200.00	216479	169280	180.63	200942	4520	156.49	3401	1285	151.01	
	815											
	830											
	845											
	850											
	900	199.20	214529	186950	180.36	195998	4485	156.11	3404	1247	150.70	
	915											
	930											
	934											
	935											
	938											
	941											
	945	200.60										
	955											
	1000	201.80	212593	284215	181.26	212596	4556	155.85	3397	1229	150.40	
	1015											
	1030			309830	183.89	247841						
	1045											
	1100	203.20	209917	281580	184.32	272985	4485	156.64	3380	1194	151.15	
	1115											
	1130	206.40										
	1138											
	1140											
	1145											
	1200	202.50	209787	281580	185.74	303003	4414	158.94	3334	1151	152.66	
	1205											
	1215											
	1230											
	1245											
	1300	201.80	209273	281580	185.55	298765	4344	160.09	3284	1098	154.17	
	1330											
	1335											
	1345											
	1350											
	1400	202.00	207975	296020	185.17	290996	4273	160.33	3235	1042	154.49	
	1430											
	1452											
	1500	200.00	207765	245600	184.19	270513	4202	160.02	3189	1014	154.49	
	1600	198.50	208880	225260	183.29	252149	4167	159.30	3132	996	153.39	
	1635											
	1700	198.50	211516	223510	182.94	245086	4061	158.55	3079	971	152.51	
	1715											
	1800	198.50	214357	221550	182.72	240848	3991	158.01	3026	943	152.02	
	1900	198.50	217293	221550	182.58	238023	3885	157.58	2974	908	151.53	
	2000	199.50	221771	226475	182.68	240142	3814	157.21	2913	879	151.23	
	2100	199.50	223474	225445	182.74	241201	3708	157.21	2846	886	151.22	
	2200	199.50	225156	229205	182.89	244027	3637	157.31	2779	865	151.42	
	2300	201.00	226666	238425	183.13	248971	3532	157.52	2712	844	151.62	
	2400	201.00	227964	231660	183.22	250737	3461	157.73	2649	823	151.83	
03-Apr-87	25											
	100	201.00	229201	229535	183.13	248971	3373	157.83	2574	798	152.06	
	200	201.00	229894	234175	183.17	249677	3288	157.93	2500	773	152.28	
	300	201.50	229370	233025	183.17	249677	3224	157.99	2426	749	152.46	
	340											
	400	201.50	229280	235500	183.18	250030	3157	158.05	2352	724	152.59	
	415											
	427											

TABLE A.2d

BEECHWOOD TO MACTAQUAC CHRONOLOGY

EVILLE AJ001 Q (m³/s*)	PRESQUE ISLE STREAM WSC 01AJ004 DISCHARGE (Calc.1 in ft³/s*)	SIMONDS - WSC 01AJ009 ELEVATION (Measured in ft*)	BECAGUIMEC STREAM WSC 01AJ010 DISCHARGE (Calc.1 in ft³/s*)	COLD STREAM WSC 01AJ011 DISCHARGE (Calc.1 in ft³/s*)	HARTLAND WSC 01AJ008 ELEVATION (Measured in ft*)	GRAFTON - NBEPC ELEVATION (Measured in ft*)	WOODSTOCK - NBEPC ELEVATION (Measured in ft)	NBEPC ELEVATION (Measured in ft)	MEDUXNEKEAG RIVER		SHOGOMOC STREAM WSC 01AK008 DISCHARGE (Calc.1 in ft³/s*)	NAKAWICK RIVER WSC 01AK007 DISCHARGE (Calc.1 in ft³/s*)	HEADPOND EL. (Measured in ft)	MACTAQUAC NBEPC				FREDERICTON - NBEPC ELEVATION (Measured in ft*)	MAUGERVILLE - NBEPC ELEVATION (Measured in ft*)	JAM POSITION	OBSERVED JAM LOCATION		TIME	COMMENTS
									WSC 01AJ003 DISCHARGE (Calc.1 in ft³/s*)	EEL - WSC 01AK008 DISCHARGE (Calc.1 in ft³/s*)				TAILRACE EL. (Measured in ft)	INFLOW (Calc.4 in ft³/s)	OUTFLOW (Calc.3 in ft³/s)				HEAD	TAIL		
6520	156.73	3394	1282	151.26		139.73	137.63	12148	2998	1451	3122	126.90	31.10	256398	271929	22.51	19.36				700	< Ice moving at Woodstock (level dropping). 4 gates cleared at Beechwood.
																					715	
6520	156.49	3401	1285	151.01		137.53	137.23	12184	3034	1459	3065	126.80	31.32	263709	269904	22.77	19.62				730	< Broken ice in Bulls Creek area. Grafton gauge no longer operational.
																					745	
																					800	< Broken ice at Bulls Creek and moving. 5 gates cleared at Beechwood.
																					815	
																					830	
																					845	
6485	156.11	3404	1247	150.70		137.93	137.93	12184	3062	1466	3009	126.80	31.90	267849	282384	23.03	19.82	8.2	< 0.5 mile below Bulls Creek		850	< Jam 0.5 mile below Bulls Creek and holding Beechwood
																					900	started spilling some ice.
																					915	
																					930	
																					934	
																					935	
																					938	
																					941	
																					945	< Beechwood started spilling a lot of ice.
6556	155.85	3397	1229	150.40		138.43	138.18	12007	3094	1473	2956	126.34	32.67	269184	295706	23.36	20.11				955	< Bulls Creek jam on east side of river. Open on west side and causing erosion along Trans Canada Highway.
																					1000	
																					1015	
																					1030	
																					1045	< Photos show a large stretch of open water near Gibson Millstream, thermal cover downstream and open water at Bulls Creek interchange/intersection. (causing erosion near road)
6485	156.64	3380	1194	151.15		138.50	138.25	11936	3122	1480	2899	125.91	33.14	270150	306301	23.69	20.31				1100	< Photos show some ice moving (~ 5% coverage) at Buckwheat Bridge, Sproules Isl and Phillips Brook.
																					1115	Beechwood ice at Florenceville gauge.
																					1130	
																					1138	
																					1140	< Channel full of broken ice above Bulls Creek. Open
6414	158.94	3334	1151	152.66		138.78	138.53	11866	3140	1483	2843	125.45	34.01	263249	324180	24.11	20.64				1145	to Riordan Island, then 1 mile sheet ice. Beechwood ice is flowing by Florenceville.
																					1200	< Ice sheet at Bulls Creek moved.
																					1205	< Trans Canada Highway at Bulls Creek closed - took guard rails. (by erosion not ice)
																					1215	
																					1230	
																					1245	
6344	160.09	3284	1098	154.17		139.78	139.83	11795	3150	1490	2786	124.96	34.10	252466	334614	24.54	20.67				1300	< Beechwood ice flowing by Deep Creek (below Hartland).
																					1330	
																					1335	< Beechwood to Woodstock is all ice.
																					1345	< Bulls Creek jam let go.
																					1350	< Photos show previous open area at Gibson Millstream now full of broken ice. Open areas in thermal ice downstream of Meductic.
6273	160.33	3235	1042	154.49		139.13	138.63	11760	3157	1490	2726	124.60	34.11	285269	332235	24.97	20.77				1400	< All ice through Beechwood.
																					1430	
6202	160.02	3189	1014	154.49		138.83	138.13	11725	3168	1494	2663	124.35	34.45	323823	330817	25.2[illegible]	20.80				1452	< 100% cover moving at Eel River. Open water above
6167	159.30	3132	996	153.39		138.43	137.78	11725	3175	1494	2599	124.75	34.26	341439	325479	25.4[illegible]	20.96				1500	Gyles Cove. Ice moving (50% coverage) at Gibson
																					1600	Millstream. 100% cover starts at Indian Village.
6061	158.55	3079	971	152.51		137.73	137.08	11725	3189	1494	2536	125.00	34.26	339905	320907	25.5[illegible]	20.96	~11	< Temple (moving)		1635	< Jam head moving at 0.2 to 0.5 m/s and breaking
																					1700	thermal ice cover into small fragments.
																					1715	< Photos show ~40% coverage at Meductic.
5991	158.01	3026	943	152.02		137.23	136.78	11654	3207	1494	2472	124.85	34.02	329208	315782	25.55	21.06				1800	
5885	157.58	2974	908	151.53		137.24	136.88	11583	3224	1494	2412	124.70	34.05	317374	307638	25.66	21.10				1900	
5814	157.21	2913	879	151.23		137.33	136.78	11513	3238	1494	2348	124.45	33.43	304785	291866	25.6[illegible]	21.13				2000	
5708	157.21	2846	886	151.22		137.88	137.73	11407	3256	1497	2278	124.30	32.77	297786	269178	25.4[illegible]	21.13				2100	
5637	157.31	2779	865	151.42		138.89	138.73	11301	3274	1497	2197	124.15	32.04	292187	250719	25.3[illegible]	21.10				2200	
5532	157.52	2712	844	151.62		139.63	139.53	11124	3288	1497	2126	123.90	31.99	290082	249980	24.9[illegible]	21.03				2300	
5461	157.73	2649	823	151.83		140.33	140.18	10771	3305	1494	2055	123.83	31.71	289826	249213	24.7[illegible]	20.93				2400	
							140.90														25	< Water over Trans Canada Highway at Bulls Creek
5373	157.83	2574	798	152.06		141.03	140.73	10453	3323	1469	1935	123.70	31.74	289088	246499	24.[illegible]	20.90				100	(again)
5288	157.93	2500	773	152.28		141.53	141.43	10135	3327	1462	1822	123.65	31.58	289014	246499	24.[illegible]	20.90				200	< Trans Canada Highway closed at Bulls Creek.
5224	157.99	2426	749	152.46		142.18	142.03	9853	3327	1459	1713	123.60	31.56	289989	244143	24.[illegible]	20.90				300	
																					340	< 1.5 ft. on Trans Canada Highway at Bulls Creek.
5157	158.05	2352	724	152.59		142.63	142.53	9570	3330	1455	1610	123.58	31.58	282942	244743	24.4[illegible]	20.90				400	
																					415	
																					427	

DATE	TIME	BEECHWOOD NBEPC TAILRACE EL. (Measured in ft)	BEECHWOOD NBEPC INFLOW (Calc. 4 in ft^3/s)	BEECHWOOD NBEPC OUTFLOW (Calc. 3 in ft^3/s)	FLORENCEVILLE WSC - 01AJ001 ELEVATION (Measured in ft*)	FLORENCEVILLE WSC - 01AJ001 DISCHARGE (Calc. 1 in ft^3/s*)	BIG PRESQUE ISLE STREAM WSC 01AJ004 DISCHARGE (Calc. 1 in ft^3/s)	SIMONDS - WSC 01AJ009 ELEVATION (Measured in ft*)	BECAGUIMEC STREAM WSC 01AJ010 DISCHARGE (Calc. 1 in ft^3/s*)	COLD STREAM WSC 01AJ011 DISCHARGE (Calc. 1 in ft^3/s*)	HARTLAND WSC 01AJ008 ELEVATION (Measured in ft*)	GRAFTON - NBEPC ELEVATION (Measured in ft*)	WOODSTOCK - NBEPC ELEVATION (Measured in ft)	NBEPC ELEVATION (Measured in ft)	MEDUXNEKEAG RIVER WSC 01AJ003 DISCHARGE (Calc. 1 in ft^3/s*)	MEDUXNEKEAG RIVER EEL - WSC 01AK008 DISCHARGE (Calc. 1 in ft^3/s*)	SHOGOMOC STREAM WSC 01AK001 - DISCHARGE (Calc. 1 in ft^3/s*)	NAKAWICK RIVER WSC 01AK007 DISCHARGE (Calc. 1 in ft^3/s*)	MACTAQUAC NBEPC HEADPOND EL. (Measured in ft)	MACTAQUAC NBEPC TAILRACE EL. (Measured in ft)	MACTAQUAC NBEPC INFLOW (Calc. 4 in ft^3/s)	MACTAQUAC NBEPC OUTFLOW (Calc. 3 in ft^3/s)	FREDERICTON - NBEPC ELEVATION (Measured in ft*)	MAUGERVILLE - NBEPC ELEVATION (Measured in ft*)	JAM POSITION	HEAD	
	439																											
	445																											
	500	201.50	229004	234530	183.25	251090	3094	158.10	2281	703	152.73		141.43	141.33	9323	3330	1448	1547	123.81	31.44	267089	248833	24.38	20.90				
	555																											
	600	202.00	227570	235200	183.26	251443	3026	158.09	2214	685	152.57		142.23	142.18	9076	3330	1444	1494	123.85	31.48	272521	246750	24.31	20.90				
	618																											
	639																											
	651																											
	700	202.00	226238	234235	183.23	251090	2963	158.09	2115	664	152.73		142.48	142.43	8864	3330	1437	1444	123.70	31.44	275145	246490	24.28	20.90				
	720																											
	743																											
	756																											
	800	202.00	224520	229615	183.11	248618	2896	158.16	2031	646	152.78		142.73	142.63	8617	3330	1434	1398	123.77	31.37	273816	252150	24.25	20.90				
	830																											
	840																										11	< 2 miles above Shogomoc St in front of Arnold Flemm house
	900	202.00	224215	227320	183.03	246852	2832	158.10	1942	625	152.79		142.88	142.83	8476	3330	1430	1402	123.75	31.44	273554	254250	24.21	20.93				
	915																											
	1000	202.00	223218	226850	183.13	248971	2772	158.06	1875	607	152.81		143.17	142.98	8476	3316	1406	1402	123.75	31.45	273836	251250	24.21	20.93				
	1015																											
	1030																											
	1100	202.00	221475	226850	183.07	247558	2744	158.11	1812	597	152.88		143.19	143.13	8511	3302	1416	1409	123.75	31.61	273040	251850	24.21	20.96				
	1110																											
	1200	202.00	218733	223620	182.88	244027	2740	158.14	1790	586	152.86		143.33	143.28	8440	3288	1427	1469	123.83	31.62	271001	252450	24.18	20.96				
	1233																											
	1300	202.00	218005	220755	182.72	240848	2691	158.01	1780	572	152.76		143.48	143.40	8405	3267	1430	1434	123.95	31.51	269400	251496	24.18	20.96				
	1330																											
	1345																											
	1400	202.00	217594	219635	182.62	238729	2634	157.89	1773	562	152.65		143.53	143.46	8299		1427	1381	123.95	31.49	268528	251796	24.18	21.00				
	1450																											
	1500	202.00	216630	219635	182.56	237670	2574	157.77	1748	547	152.57		143.65	143.53	8193		1427	1370	124.00	31.50	265242	250596	24.18	20.96				
	1600	201.50	216073	217190	182.51	236611	2539	157.70	1702	540	152.51		143.75	143.63	8122		1423	1367	124.05	31.47	260129	249096	24.18	20.96				
	1700	201.50	216118	214800	182.42	234845	2525	157.64	1667	537	152.49		143.75	143.63	8158		1420	1363	124.10	31.56	259236	252876	24.15	20.93				
	1800	201.50	215687	214800	182.30	232726	2507	157.58	1639	540	152.39		143.88	143.81	8193		1420	1360	124.00	31.80	256511	260046	24.11	20.93				
	1900	200.50	215258	212865	182.20	230607	2490	157.52	1610	544	152.26		143.91	143.82	8193		1416	1356	124.00	31.85	255570	259404	24.08	20.96				
	1905																											
	1920																											
	2000	200.50	213734	213880	182.16	229901	2476	157.44	1582	547	152.20		143.91	143.81	8158		1416	1349	123.90	31.99	253518	261248	24.18	21.00				
	2030																											
	2100	200.50	214298	213880	182.20	230607	2458	157.35	1561	547	152.14		143.53	143.63	8017		1413	1346	123.84	31.78	252970	261248	24.18	21.00				
	2200	200.50	213922	214200	182.22	230960	2440	157.27	1536	544	151.90		143.03	143.13	7911		1409	1342	123.80	31.96	250762	261436	24.21	21.00				
	2300	200.50	212810	214200	182.20	230607	2426	157.19	1533	537	151.86		142.93	142.88	7769		1409	1317	123.90	31.97	249355	261247	24.21	21.00				
	2400	200.50	211571	214700	182.19	230607	2408	157.14	1526	530	151.78		142.78	142.71	7663		1402	1293	123.82	31.84	247981	258136	24.25	21.00				
04-Apr-87	100	200.50	210219	211815	182.16	229901	2394	157.08	1519	523	151.71		142.61	142.56	7522		1395	1264	123.81	31.75	247954	262186	24.25	21.00				
	200	200.00	209255	212920	182.11	228841	2366	157.03	1515	512	151.64		142.48	142.41	7381		1388	1240	123.81	31.81	247901	260086	24.25	21.00				
	300	200.00	207053	210745	181.97	226369	2338	156.97	1508	505	151.53		142.33	142.28	7275		1381	1211	123.83	31.92	246804	260086	24.25	21.00				
	400	200.00	205844	210745	181.91	224957	2310	156.91	1501	498	151.39		142.08	142.08	7134		1377	1190	123.82	31.62	246494	256786	24.28	21.00				
	500	200.00	202457	208745	181.86	224250	2285	156.81	1487	491	151.25		141.93	141.83	7028		1370	1165	123.80	31.83	245024	260086	24.28	21.00				
	550																											
	600	200.00	199864	206440	181.77	222485	2257	156.69	1469	480	151.11		141.68	141.63	6886		1363	1141	123.79	31.77	244686	261286	24.28	21.00				
	700	199.50	197690	203620	181.53	217894	2228	156.57	1451	470	150.94		141.28	141.23	6780		1356	1119	123.75	31.67	240594	259953	24.28	21.00				
	710																											
	800	199.00	196198	201490	181.39	215068	2200	156.44	1434	463	150.74		141.14	141.01	6675		1349	1095	123.75	31.91	237057	265653	24.28	21.00				
	900	199.00	194074	201490	181.34	214362	2172	156.29	1416	452	150.54		140.84	140.68	6569		1342	1074	123.70	31.91	233324	264021	24.31	21.03				
	928																											
	1000	199.00	192117	200500	181.34	214362	2147	156.16	1398	445	150.35		140.50	140.36	6498		1338	1056	123.70	31.90	233916	266721	24.28	21.03				
	1100	199.00	190981	198590	181.17	210831	2119	156.02	1377	438	150.14		140.18	139.98	6463		1331	1045	123.65	31.90	231673	261021	24.28	21.06				
	1200	198.50	190095	190960	180.90	205886	2091	155.93	1356	434	149.92		139.81	139.68	6392		1328	1038	123.55	31.80	228364	263428	24.28	21.06				
	1300	198.50	189004	192690	180.81	204121	2062	155.68	1338	431	149.71		139.48	139.38	6321		1324	1028	123.50	31.78	223734	261390	24.31	21.06				
	1400	198.20	187237	189425	180.75	203061	2038	155.50	1317	427	149.51		139.13	138.98	6251		1317	1028	123.45	31.89	222898	262290	24.34	21.06				
	1500	198.00	186018	188145	180.62	200942	2009	155.37	1296	420	149.32		138.68	138.63	6180		1314	1035	123.45	31.73	222072	262290	24.31	21.06				
	1600	198.00	185125	189400	180.57	199883	2002	155.24	1278	420	149.13		138.35	138.23	6145		1307	1042	123.45	31.74	[illegible]911	251274	24.31	21.06				
	1626																											
	1700	198.00	183462	189700	180.59	200236	1995	155.15	1271	427	148.94		137.93	137.83	6074		1303	1056	123.45	31.66	217125	254100	24.29	21.10				
	1800	198.00	180138	189400	180.55	199530	1992	155.08	1261	431	148.80		137.43	137.43	6039		1300	1067	123.45	31.42	215919	242022	24.25	21.06				
	1900	198.00	175217	186745	180.39	196705	1985	155.02	1250	438	148.68		137.13	136.98	6004		1296	1077	123.45	31.24	215352	246822	24.18	21.06				
	2000	198.00	177563	182965	180.24	193879	1981	154.90	1247	441	148.56		136.80	136.63	5968		1289	1091	123.50	31.07	211712	239808	24.11	21.03				
	2100	198.00	179528	178685	180.08	191054	1974	154.72	1250	449	148.33		136.48	136.33	5933		1285	1095	123.60	30.89	211011	237482	24.0[illegible]	21.03				
	2200	197.50	174784	174250	179.89	187523	1971	154.54	1264	449	148.06		136.18	135.93	5898		1282	1098	123.60	31.01	208332	237182	23.95	21.00				
	2300	196.50	171424	172280	179.71	184344	1964	154.38	1275	445	147.87		135.75	135.53	5862		1275	1095	123.70	30.83	207264	235011	23.92	21.00				
	2400	196.50		172290	179.66	183285	1956	154.23	1289	445	147.69		135.43	135.23	5827		1271	1081	123.73	30.70	203466	232311	23.79	20.96				

TABLE A.2e

BEECHWOOD TO MACTAQUAC CHRONOLOGY

MACTAQUAC NBEPC				OBSERVED JAM LOCATION				
INFLOW (Calc. 4 in ft^3/s)	OUTFLOW (Calc. 3 in ft^3/s)	FREDERICTON-NBEPC ELEVATION (Measured in ft*)	MAUGERVILLE-NBEPC ELEVATION (Measured in ft*)	JAM POSITION	HEAD	TAIL	TIME	COMMENTS
							439	
							445	
267089	248833	24.38	20.90				500	
							555	
272521	246750	24.31	20.90				600	
							618	
							639	
							651	
275145	246490	24.28	20.90				700	
							720	
							743	
							756	
273816	252150	24.25	20.90				800	
				11	< 2 miles above Shogomoc Stream in front of Arnold Flemming's house	< Above Gibson Millstream (Dugan Road)	830	
273554	254250	24.21	20.93				840	
							900	
							915	
273836	251250	24.21	20.93				1000	< Photos show tail at Gibson Millstream church,
							1015	and ice still running (~ 20% coverage).
							1030	
273040	251850	24.21	20.96				1100	
							1110	
271001	252450	24.18	20.96				1200	< Photos show ice accumulated at tail of jam - loose
							1233	ice on surface.
269400	251496	24.18	20.96				1300	
							1330	
							1345	
268528	251796	24.18	21.00				1400	
							1450	< Jam unchanged.
265242	250596	24.18	20.96				1500	
260129	249096	24.18	20.96				1600	
259236	252876	24.15	20.93				1700	
256511	260046	24.11	20.93				1800	< Photos show tail well above Gibson Millstream. Open
255570	259404	24.08	20.96				1900	water for a short stretch at Hays Brook.
							1905	
							1920	
253518	261248	24.18	21.00				2000	
							2030	< Woodstock started to drop.
252970	261248	24.18	21.00				2100	< Ice started to run from the "interval" in the
250762	261436	24.21	21.00				2200	Meduxnekeag. ~ (Approximately 1/4 moved out) Bulls
249355	261247	24.21	21.00				2300	Creek level down 13 inches.
247981	258136	24.25	21.00				2400	
247954	262186	24.25	21.00				100	
247901	260086	24.25	21.00				200	
246804	260086	24.25	21.00				300	
246494	256786	24.28	21.00				400	
245024	260086	24.28	21.00				500	
							550	
244686	261286	24.28	21.00				600	
240594	259953	24.28	21.00				700	< Ice moved from Bulls Creek area. Meduxnekeag ice
							710	clear of railroad bridge.
237057	265653	24.28	21.00				800	< Photos show tail receeding and now below Gibson
233324	264021	24.31	21.03				900	Millstream. Open lead at Eel River.
							928	
233916	266721	24.28	21.03				1000	
231673	261021	24.28	21.06				1100	
228364	253428	24.28	21.06				1200	
223734	261390	24.31	21.06				1300	
222898	262290	24.34	21.06				1400	
222072	262290	24.31	21.06				1500	
218911	251274	24.31	21.06				1600	
							1626	
217125	254100	24.29	21.10				1700	
215919	242022	24.25	21.06				1800	
215352	246822	24.18	21.06				1900	
211712	239808	24.11	21.03				2000	
211011	237482	24.05	21.03				2100	
208332	237182	23.95	21.00				2200	
207264	235011	23.92	21.00				2300	
203466	232311	23.79	20.96				2400	

DATE	TIME	TAILRACE EL. (Measured in ft)	BEECHWOOD NBEPC INFLOW (Calc. 4 in ft³/s)	BEECHWOOD NBEPC OUTFLOW (Calc. 3 in ft³/s)	FLORENCEVILLE WSC - 01AJ001 ELEVATION (Measured in ft*)	FLORENCEVILLE WSC - 01AJ001 DISCHARGE (Calc. 1 in ft³/s*)	BIG PRESQUE ISLE STREAM WSC 01AJ004 DISCHARGE (Calc. 1 in ft³/s*)	SIMONDS - WSC 01AJ009 ELEVATION (Measured in ft*)	BECAGUIMEC STREAM WSC 01AJ010 DISCHARGE (Calc. 1 in ft³/s*)	COLD STREAM WSC 01AJ011 DISCHARGE (Calc. 1 in ft³/s*)	HARTLAND WSC 01AJ008 ELEVATION (M
05-Apr-87	100	196.50	173000	179.65	183285	1935	154.09	1303	441	147.52	
	200		167745	179.51	180813	1914	153.98	1314	438	147.41	
	300	196.50		179.36	178341	1893	153.89	1328	431	147.27	
	400	196.50	166825	179.25	176222	1875	153.78	1338	427	147.12	
	500	196.00	165120	179.21	175516	1858	153.67	1346	424	146.97	
	600	195.00	165120	179.10	173397	1840	153.56	1349	420	146.84	
	700	196.00	162065	178.93	170571	1822	153.45	1346	413	146.72	
	800	196.00	159060	178.50	163155	1812	153.29	1342	410	146.58	
	900	196.00	151765	178.53	163862	1805	153.09	1338	406	146.28	
	1000	196.00	158705	178.68	166334	1794	152.90	1331	399	146.06	
	1100	196.00	158875	178.73	167040	1783	152.81	1321	396	146.03	
	1200	196.00	159450	178.72	166687	1776	152.72	1307	388	146.04	
	1300	196.50	158950	178.58	164568	1766	152.73	1296	385	146.05	
	1400	196.50	155400	178.50	163155	1755	152.82	1282	381	146.00	
	1500	196.50	155400	178.41	161743	1745	152.90	1268	378	145.86	
	1600	196.50	153020	178.35	160683	1737	152.79	1254	374	145.73	
	1700	196.50	153020	178.32	160330	1727	152.69	1240	378	145.63	
	1800	196.50	152440	178.19	157858	1716	152.59	1225	374	145.54	
	1900	196.50	149795	178.06	155739	1713	152.49	1215	374	145.45	
	2000	196.50	147130	177.90	153267	1706	152.39	1215	374	145.36	
	2100	196.00	145225	177.75	150795	1702	152.29	1215	374	145.18	
	2200	196.00	142170	177.61	148323	1699	152.19	1211	378	144.99	
	2300	196.00	139935	177.47	145851	1695	152.09	1211	374	144.79	
	2400	196.00	137855	177.35	144085	1688	151.89	1211	371	144.64	

* Converted from metric to imperial using
  1 m^3/s = 35.315 cfs
  1 m = 3.2808 ft

calc.1 - calculated using a stage-discharge relationship
calc.2 - calculated by backrouting outflow discharge taking account of storage changes
calc.3 - calculated as plant discharge plus spill discharge
calc.4 - calculated using the SOCH routing model -- calculated ignoring effects of jam storage and release mechanisms

note - all elevations are referred to Geodetic Survey of Canada Datum
     - italic comments are inferences from the data. All other comments are actual observations.

TABLE A.2f

BEECHWOOD TO MACTAQUAC CHRONOLOGY

ENCEVILLE OIAJ001 Q in ft^3/s*)	BIG PRESQUE ISLE STREAM WSC OIAJ004 DISCHARGE (Calc.1 in ft^3/s*)	SIMONDS - WSC OIAJ009 ELEVATION (Measured in ft)	BECAGUIMEC STREAM WSC OIAJ010 DISCHARGE (Calc.1 in ft^3/s*)	COLD STREAM WSC OIAJ011 DISCHARGE (Calc.1 in ft^3/s*)	HARTLAND WSC OIAJ008 ELEVATION (Measured in ft*)	GRAFTON - NBEPC ELEVATION (Measured in ft*)	WOODSTOCK - NBEPC ELEVATION (Measured in ft)	NBEPC ELEVATION (Measured in ft)	MEDUXNEKEAG RIVER WSC OIAJ003 DISCHARGE (Calc.1 in ft^3/s*)	EEL - WSC OIAK008 DISCHARGE (Calc.1 in ft^3/s*)	SHOGOMOC STREAM WSC OIAK001 DISCHARGE (Calc.1 in ft^3/s*)	NAKAWICK RIVER WSC OIAK007 DISCHARGE (Calc.1 in ft^3/s*)	MACTAQUAC NBEPC HEADPOND EL. (Measured in ft)	TAILRACE EL. (Measured in ft)	INFLOW (Calc.4 in ft^3/s)	OUTFLOW (Calc.3 in ft^3/s)	FREDERICTON - NBEPC ELEVATION (Measured in ft*)	MAUGERVILLE - NBEPC ELEVATION (Measured in ft*)	JAM POSITION	OBSERVED JAM LOCATION HEAD	TAIL	TIME	COMMENTS
1935	154.09	1303	441	147.52		135.13	134.89	5792		1268	1067	123.65	30.52	203044	230158	23.75	20.93				100	
1914	153.98	1314	438	147.41		134.75	134.58	5756		1264	1056	123.80	30.25	200278	220203	23.69	20.93				200	
1893	153.89	1328	431	147.27			134.23	5686		1261	1042			198086							300	
1875	153.78	1338	427	147.12		134.40	134.01	5650		1254	1031	123.90	30.04	194345	214498	23.59	20.90				400	
1858	153.67	1346	424	146.97		133.81	133.63	5615		1250	1017	123.80	29.90	193567	206826	23.49	20.87				500	
1840	153.56	1349	420	146.84		133.58	133.28	5544		1247	1006	124.00	29.65	192200	203838	23.39	20.83				600	
1822	153.45	1346	413	146.72		133.14	132.98	5509		1243	992	124.10	29.45	190227	194616	23.26	20.80				700	
1812	153.29	1342	410	146.58		133.00	132.63	5474		1240	982	124.20	28.97	187313	191190	23.10	20.77				800	
1805	153.09	1338	406	146.28		132.95	132.58	5403		1232	968	124.30	27.76	181751	168174	22.90	20.67				900	
1794	152.90	1331	399	146.06		132.60	132.28	5368		1229	957	124.40	27.41	180568	153699	22.60	20.64				1000	
1783	152.81	1321	396	146.03		132.55	132.08	5297		1225	943	124.50	26.96	183125	142534	22.31	20.44				1100	
1776	152.72	1307	388	146.04		132.40	131.97	5262		1222	929	124.80	27.03	183928	147367	21.98	20.44				1200	
1766	152.73	1296	385	146.05		132.10	131.73	5227		1215	925	125.00	26.89	179126	146392	21.85	20.18				1300	
1755	152.82	1282	381	146.00		131.75	131.13	5156		1211	925	125.20	26.67	177534	151113	21.69	20.11				1400	
1745	152.90	1268	378	145.86		131.62	131.08	5121		1208	925	125.70	26.43	174029	145371	21.55	19.78				1500	
1737	152.79	1254	374	145.73		131.56	131.05	5085		1201	925	125.85	26.71	174982	149435	21.39	19.91				1600	
1727	152.69	1240	378	145.63		131.58	131.05	5015		1197	925	126.07	26.60	172886	149712	21.29	19.85				1700	
1716	152.59	1225	374	145.54		131.46	130.95	4979		1190	929	126.20	26.53	173826	149824	21.23	19.78				1800	
1713	152.49	1215	374	145.45		131.40	130.88	4979		1187	929	126.35	26.50	170389	152145	21.16	19.75				1900	
1706	152.39	1215	374	145.36		131.30	130.82	4944		1183	929	126.60	26.42	168743	150261	21.13	19.68				2000	
1702	152.29	1215	374	145.18		131.10	130.63	4944		1176	929	126.75	26.14	165664	146970	21.03	19.65				2100	
1699	152.19	1211	378	144.99		130.88	130.40	4909		1172	929	127.05	26.13	164736	140763	20.93	19.55				2200	
1695	152.09	1211	374	144.79		130.80	130.26	4909		1169	929	127.25	26.11	161787	138456	20.87	19.52				2300	
1688	151.89	1211	371	144.64		130.81	130.30	4873		1162	932	127.50	25.97	161787	143292	20.73	19.42				2400	

ount of storage changes

gnoring effects of jam storage and release mechanisms

Datum

omments are actual observations.